SECTION 400.00 – GUIDELINES FOR SUBSURFACE INVESTIGATIONS

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A foundation, retaining wall, highway, etc. cannot be properly designed unless the designer obtains the engineering properties of the subsurface materials involved. This necessary information is developed from a subsurface investigation, which should include planning, reconnaissance, field exploration, laboratory testing, engineering analyses, and a written report.

The goal of any subsurface investigation should be to provide characterization of the conditions encountered by performing high quality work. All subsurface investigations shall be performed under the direct supervision of experienced professionals who are either Professional Engineers or Professional Geologists registered in the State of Idaho. Any subordinate work or field work for simple projects such as pavement rehabilitation, roadway widening without significant structures, cuts or fills, or sand sheds could be performed by a non-licensed engineer or geologist, or other certified materials technician working under the direct supervision of a licensed professional as described above, and with the approval of the District Materials Engineer. Investigations involving bedrock or rock slope conditions shall be performed under the direction and responsible charge of a Professional Geologist or Professional Engineer Registered in Idaho (with experience and qualifications as appropriate to the project and setting).

The subsurface investigation program scope must consider the initial cost, the risk associated with the size and complexity of the project, and the anticipated conditions. Incomplete information must otherwise be compensated for by the use of a larger safety factor in design, which may increase construction costs.

The cost of a thorough subsurface investigation for a large project is usually small compared to the potential savings that can be realized by fully utilizing the investigation results in design and construction, or when compared to the costs associated with a failure or construction claim due to erroneous design assumptions or changed conditions.

No matter how complete the subsurface investigation program, there always remains an element of uncertainty concerning the exact nature of the subsurface conditions. Laboratory tests performed on a few soil or rock samples, unlike tests on other structural material types, do not necessarily provide a satisfactory basis for design because: (1) the samples tested may not represent the critical materials or condition, and (2) the engineer is concerned about the behavior of the soil or rock deposit as a whole rather than the action of individual samples.

The importance of close communication between the investigating personnel (geologist, materials engineer, and geotechnical engineer), and the design and construction personnel cannot be overemphasized. This communication is necessary to ensure that recommendations are correctly interpreted and recognized in design, and implemented during construction. Also, as construction exposes subsurface conditions that appear to be problem areas and/or different from conditions reflected in design, materials and design personnel should be consulted before any changes are made.

Before beginning any subsurface investigation, all available pertinent information sources should be reviewed as part of the project planning process. A thorough review of available historic and geologic information during the planning phase can produce a more efficient design, and reduce the potential for proposed structure performance problems and/or construction claims for changed conditions.

Following is a partial list of existing historic, geologic, topographic and hydrologic information sources:

- Previous subsurface investigations at or near the proposed project site.
- Existing construction records or other records of past performance problems for highway and other facilities in the area. Potential sources for this type of information are local and district highway maintenance personnel.
- U. S. Geological Survey (USGS) maps, reports, and other publications.
- USGS and/or FEMA flood zone maps.
- Department of Agriculture Natural Resources Conservation Service (NRCS, formerly SCS) maps.
- Local university libraries and geology departments.
- Earthquake, seismicity and fault maps prepared by USGS, local university geology departments, et al.
- Aerial photographs (USGS, USFS, USDA NRCS, private vendors, etc.).

The geotechnical engineer or geologist in responsible charge of the subsurface investigation should make a preliminary site visit along with the lead design engineer before finalizing the subsurface investigation plan to better understand site access and working constraints, as well as how the proposed project is to relate to significant site topographic, geologic, geotechnical and hydraulic features. The following should be noted during the site visit:

- Nearby structures should be evaluated to assess their foundation performance, structure usage, and potential for damage due to vibration or settlement caused by the proposed construction.
- On water crossings, stream banks should be evaluated for scour potential, and the streambed inspected for evidence of recent soil deposits not previously indicated.
- Note any feature(s) that may affect the proposed boring or test pit program, such as access limitations, existing structures, overhead utilities, signs of buried utilities, or other property restrictions.
- Note any feature that may be useful in the engineering analysis, such as the angle and apparent stability (or lack thereof) of nearby existing slopes, and the stability of any nearby open excavations.
- Observe all nearby drainage features or other water sources, including signs of seasonal (or historic) high water, high ground water tables, springs or seeps.
- Note any other features that may need any additional subsurface or geophysical investigation.

All borings and test pits should be located horizontally and vertically by a licensed surveyor. Where a surveyor is not available, other appropriate location methods such as taping could be used. All taping should be done from known site features to an accuracy of 1 foot (0.3 meter) or less. When a topographic survey is available, boring/test pit elevations could be estimated by interpolation between contours. However, in steep terrain where contour intervals change rapidly, the elevations should be verified by survey methods. All elevations should be reported on the exploratory logs to the nearest 3 inches (75 mm), if practical. Regardless of how the surveying is accomplished, the elevation datum must be identified and provided in the corresponding phase report. All boring or test locations should be preliminarily recorded by hand held GPS for later reference. All final locations shall be reported in Idaho State Plane Coordinates, as well as project specific (i.e. station and offset) location.

All test pit excavation and temporary shoring should be accomplished in accordance with OSHA regulations.

Written permission must be obtained from the property owners (Form ITD-363), as well as all required permits (e.g. Corps of Engineers 404), and environmental and cultural clearances prior to any drilling or test pitting activity. An approved traffic control plan and a permit to work within the ITD right-of-way may also be required. Additionally, a utility locate should be performed for all sites as described in Section 445.00 before beginning any subsurface investigation. A Temporary Water Appropriation Permit from the Idaho Department of Water Resources may be required if drilling water is taken from surface water sources.

Subsurface investigations for all aggregate and borrow deposits shall be performed in accordance with Idaho Test T142 “Investigation of Aggregate and Borrow Deposits”.

The Geotechnical Engineer shall be contacted for guidance concerning subsurface investigations for tunnels or any other structures not specifically described in these guidelines.

SECTION 405.00 – SUBSURFACE INVESTIGATION FOR BRIDGE STRUCTURES

405.01 Introduction. This section provides guidelines for planning and conducting subsurface investigations for bridge and culvert structures.

405.02 Preliminary Study of Structure Site Data. The district Project Development Section should prepare and submit Form ITD-210, Hydraulic Structures Survey, with all investigation requests for culverts or bridges crossing live or intermittent stream courses, canals, or other water.

All available information that can be provided by the Materials and Bridge Design Sections to aid the preliminary planning process should be evaluated. The following information is normally needed:

- Recommended structure type.
- Highest permissible bottom of footing elevation for shallow foundations.
- Estimated pile or drilled shaft length(s) for deep foundations.
- Anticipated foundation material character.

Prior Department approval for the recommended structure type will be required for all structures that cross waterways. This is true of all structures where rivers, irrigation laterals, canals, and live streams are involved. In many cases, several structure types could be used, but if piers in the stream or certain construction methods will not be permitted, the number of possible structure types is reduced.

The highest possible bottom of footing elevation determination is necessary to make sure the structure footings are set deep enough below the stream bed to prevent a structure failure caused by the footings being undermined by scour. A streambed and contour map study, as well as the hydraulic information prepared by the district Project Development Section described above will aid in making this determination.

The anticipated piling or drilled shaft length should be estimated if the structure is in a new location. If the proposed structure is a replacement of an existing structure, the existing pile or drilled shaft penetration data could serve as a guide to estimate anticipated pile or drilled shaft penetration depths. This information may generally be found in Bridge Design Section files for structures built by the Idaho Transportation Department.

The information on the foundation material character is very important as it affects the choice of equipment that will be used for the subsurface investigation. Also, see Section 445.00 as a guide to select proper sampling equipment and methods.

405.03 Preliminary Investigation. The district Project Development Section will furnish the Bridge Design Section with a site topographic map together with the finished roadway approach profile grades and alignments. The Project Development Section should also provide all required environmental and cultural resource clearances necessary for performance of the subsurface investigation. Also, Form ITD-210 will be submitted to the Bridge Design Section at this time for structures over drainages and channels.

In some instances, the District Materials Section may initially drill one (1) or two (2) preliminary borings at selected locations, preferably at each end of the proposed structure. The boring logs and their interpretation would then be incorporated by the Materials Section into a preliminary report, where they would be reviewed and forwarded to the Bridge Design Section with applicable comments.

After the Bridge Design Section has approved the structure type and size, they will send copies of Form ITD-210, when available, along with the topographic map showing pier and abutment locations to the District Materials Section. Approximate dead and dead plus live loads will be included in the investigation request. The District Materials Engineer or Geologist (or other geotechnical engineer or geologist in responsible charge of the subsurface investigation) will then develop the recommended subsurface investigation plan based on their knowledge of the site.

405.04 Planning the Exploration. The District Materials Engineer and/or District Geologist (or other geotechnical engineer or geologist in responsible charge of the work) will make a site reconnaissance to determine the required investigation type and equipment, sampling or field testing procedure(s), etc. In areas of known subsoil conditions, this may not be necessary. Property ownership must be determined and written permission for right of entry and investigation must be obtained using form ITD-363, Right-of-Way Contract. Arrangements for paying for property damage are covered in the Right-of-Way Contract.

All available literature and other data should be reviewed prior to starting field work. Topographic maps that denote landforms and drainage, geologic maps, and aerial photographs should all be reviewed before beginning the drill program. Data from well drill records and previous subsurface exploration programs will yield valuable information in the determination of the type of subsurface investigation program to undertake.

A preliminary study should also include the effects of stream scour. From this, the minimum investigation boring depths can be determined. Stream bed elevations must also be known before determining minimum boring depth.

After all of the above described information is evaluated, the District Materials Engineer and/or the District Geologist (or other geotechnical engineer or geologist in responsible charge of the work) will finalize the subsurface investigation plan.

405.05 Exploration. Subsurface conditions must be investigated by means of borings and/or test pits. The goal of the subsurface investigation program should be a high quality characterization of the conditions encountered. Continuous sampling methods should be employed wherever appropriate for the subsurface conditions. These may include continuous sampling augers, rock coring, vibro-coring or continuously driven devices. Casing advancer or drill-and-drive techniques should be used only in limited areas where the conditions are well understood, and recovery of a core sample would not enhance the knowledge of the site. Explorations utilizing non-continuous sampling should be supplemented by detailed observations of the drilling action, drill cuttings or return, or other characteristics in order to provide a continuous boring log.

Borings and test pits must be referenced to centerline stations with offset distances and must show elevations referenced to a datum. Each exploration log shall contain a location in reference to the Idaho State Plane Coordinate System. This information is important for future reference and incorporation into a GIS system. Representative disturbed samples must be taken for soil classification and moisture content tests. Undisturbed samples are taken if the soil in situ unit weight, or other soil engineering properties, such as shear or consolidation are to be determined by laboratory tests. The groundwater level and any artesian conditions, if they exist, must be identified and properly documented.

The following sections present guidelines regarding the number and depth of borings or test pits typically needed to develop an adequate picture of the subsurface conditions.

The Bridge Design Section will provide a layout showing proposed foundation locations and footing elevations. District Materials personnel or the geotechnical engineer (or geologist) in responsible charge of the subsurface investigation will propose boring locations utilizing the foundation layout drawing. The proposed layout should then be taken to the drill site to determine the boring locations. Drill hole collar elevations as well as station control must be determined.

Permission must be obtained from the property owners, as well as all required permits (e.g. Corps of Engineers 404), and environmental and cultural clearances prior to any drilling activity. Additionally, a utility locate should be performed for all sites as described in Section 445.00 before beginning any subsurface investigation. A Temporary Water Appropriation Permit from the Idaho Department of Water Resources may be required if drilling water is taken from surface water sources.

405.05.01 Boring Locations. Borings shall be located in accordance with the structure layout plan submitted by the Bridge Design Section. The number and position of these borings shall be considered a minimum. Additional borings will be made when the continuity of the subsurface materials is poor or when additional data is considered necessary to address anticipated design problems. Geophysical test methods can also be used to investigate subsurface conditions between test holes.

At least one (1) boring is required per footing (abutment or pier). On bridges more than 100 ft. (30 m) wide, where foundation conditions are variable, or where shallow foundations are expected to be founded on rock, additional borings with a minimum of one (1) boring at each end of the proposed footing location are required. For structure widenings, the total number of borings may be reduced, depending on the information available for the existing structure. On multiple short-span bridges, particularly in uniform subsurface conditions, borings at every footing may not be needed. Where appropriate in obtaining the needed information, Dutch Cone (CPT) or solid cone penetrometer tests can also be used.

405.05.02 Boring Depths. Bridges will typically be supported on materials at least 3 ft. (1 m) below the lowest adjacent grade, stream bottom, or scour elevation. Although the economics vary between bridges, spread footings will not commonly be bottomed deeper than about 15 ft. (4.5 m) below adjacent grade.

Borings shall be advanced through any soils unsuitable for support and into competent material. Borings should extend to a depth of at least five (5) times the anticipated footing width; or 50% deeper than anticipated pile or drilled shaft penetration, up to a maximum depth of 150 feet (45 meters). Where boring depths in excess of 150 feet (45 meters) are anticipated, approval from the District Materials Engineer shall be obtained before the subsurface investigation plan can be finalized. If the subsurface investigation has already begun, boring depths in excess of 150 feet (45 meters) shall be approved by the District Materials Engineer. The borings should penetrate deep enough below the estimated pile penetration depth to define any compressible material within the zone of influence of the foundation (typically two (2) to three (3) times the least pile or drilled shaft group outside dimension). Advance borings by rock coring methods a minimum of 10 ft. (3 m) into rock if encountered within the planned exploration depth. Approximate abutment and pier loads, supplied by the Bridge Design Section, may be used to estimate footing width or pile (or drilled shaft) group size, which will aid in determining required boring depths.

Required boring depths at bridge locations will also depend upon the material encountered. Borings located beyond the stream scour limits should be treated similar to those for underpasses and overpasses as described below. It is usual and good practice for the first boring to be considered as a "seeking" one and be carried to 50 ft. (15 m) or more below stream scour depth. The position of this first boring should be selected with care to obtain the maximum information. The "seeking hole" should in all cases examine the stratigraphy and become a prime correlation hole. Where solid rock is encountered in the “seeking hole”, core penetration of at least 10 ft. (3 m) into competent rock is required. If the material encountered is non-granular (e.g., silt and clay), the boring should continue to a depth so that adequate data to determine pile length and support are obtained. Whenever rock is encountered, the drill holes are to be advanced into the rock line and core penetration of at least 10 ft. (3 m) into competent rock is required.

Overpasses and underpasses are generally dry land structures and, as such, are not treated in the same manner as bridges over waterways. If the subsurface material encountered consists of competent materials and shallow foundations are anticipated, borings should be made to a minimum depth of about five (5) times the estimated footing width below the proposed footing elevation. It is a good practice to ensure an adequate depth of competent material to support the structure. A depth of 50 ft. (15 m) for this boring is generally adequate. If solid rock is encountered, core penetration of at least 10 ft. (3 m) into competent rock will be required. If the material encountered is not suited for shallow foundations, and deep foundations are anticipated, the borings should continue until adequate data to determine the required pile (including test piles) or drilled shaft lengths and support are obtained, but should not be less than 50 feet (15 meters) deep.

405.06 Reporting. The structure foundation investigation results are presented in a Phase IV Foundation Investigation Report and Foundation Plat. The report and plat requirements are presented in Section 250.00.

SECTION 410.00 – SUBSURFACE INVESTIGATIONS FOR BUILDINGS (OTHER THAN SAND SHEDS)

410.01 Introduction. This section provides guidelines for planning and conducting subsurface investigations to provide information required for foundation design for ITD office buildings and maintenance buildings.

410.02 Building Records. Available information on subsurface conditions at proposed building sites should be studied before beginning any subsurface investigation. The following information can be obtained from the ITD Headquarters or District Maintenance Sections to aid in planning the subsurface investigation:

- Anticipated structure type,
- Anticipated foundation depths.

410.03 Exploration. The number of borings and/or test pits needed to adequately explore a building site will depend on the size and shape of the building and the variability of the subsurface conditions. No hard and fast rules are proposed, but the number of borings or test pits should be adequate to define the subsurface profile and provide samples of the various strata for laboratory analysis.

As a general guide, at least two (2) borings or test pits are needed for buildings with a footprint of up to about 2,000 square feet (185 m^2). A single boring or test pit may be adequate if a building is very small. At least one (1) additional boring or test pit is required for each 2,000 square feet (185 m^2) additional foot print area up to about 10,000 square feet (930 m^2).

For larger buildings, an additional boring or test pit is needed for each additional 5,000 to 10,000 square feet (460 to 930 m^2). These guidelines presume relatively uniform site conditions and building loads.

Additional borings or test pits are required at locations of concentrated heavy loads, or if the building footprint is unusually shaped, or there are stringent differential settlement requirements, or where the subsurface conditions are erratic or change rapidly, and if the site has been previously filled. Additional borings or test pits may be needed along utility corridors, particularly sewer lines where shallow rock or strongly cemented soils are suspected.

Backhoe excavated test pits may suffice for very lightly loaded buildings or where competent soils (dense sand, gravel, or rock) are shallow.

Most buildings constructed by ITD are supported on shallow spread footings. Typical maintenance building column loads are on the order of 10 to 15 tons (90 to 135 kN). These loads can be used to estimate footing widths and, therefore, aid in estimating minimum boring or test pit depths. Approximate loads for unusual building or foundation configurations should be requested from the Headquarters or District Maintenance Section.

Borings and test pits should extend to a depth below the probable footing elevation equal to at least five (5) times the approximate anticipated shallow footing width. If rock or dense gravel strata are encountered at shallower depths, borings and test pits should extend at least 10 feet (3 meters) into the dense material. All borings and test pits should penetrate below the planned depth of basement or other excavations by the amount described above, regardless of the type of material. All borings or test pits should extend through any loose, soft, or otherwise unsuitable soil layers.

The proposed building footprint should be accurately located by survey methods before the subsurface investigation begins. Care should be taken to locate test pits in the field so that the bearing soil beneath proposed footing areas is not disturbed during the subsurface investigation, and so that the test pit can be re-located easily and remediated, should the proposed building be shifted from it's original planned location or the building configuration be changed during the project development phase.

SECTION 415.00 – SUBSURFACE INVESTIGATIONS FOR RETAINING WALLS

415.01 Introduction. This section provides guidelines for subsurface investigations for retaining walls with shallow footings, including gravity and semi-gravity walls, cantilever walls, and Mechanically Stabilized Earth (MSE) walls.

415.02 Exploration. Borings or test pits for retaining walls should be spaced 100 to 200 feet (30 to 60 meters) apart on uniform sites, and as close to the wall alignment as possible. A closer spacing should be used where subsurface conditions are erratic. Some borings or test pits may be needed in front of and behind wall locations to define the subsurface conditions perpendicular to the wall. A minimum of two (2) borings or test pits are required for each wall.

Extend borings and test pits to a depth below the bottom of the wall equal to at least twice the height of the wall, or to a minimum depth of 10 feet (3 m) into competent material. For walls with deep foundations, use the guidelines presented above in Section 405.00 for bridge structures.

For MSE walls, follow the guidelines for embankments presented in Section 425.00, Roadways. Borings and test pits for MSE walls should be located beneath the reinforced soil zone.

SECTION 420.00 – SUBSURFACE INVESTIGATIONS FOR DRAINAGE STRUCTURES

420.01 Introduction. This section is intended for culverts, arches, bottomless arches supported on footings, box culverts, etc., which may be used as drainage structures, or machine or stock passes. Exploration for most culverts should be accomplished in conjunction with exploration for embankments as described in Section 425.00. Specific foundation exploration for culverts is required where foundation conditions will require treatment and/or removal of unsuitable soil, or where significant settlement is anticipated.

420.02 Exploration. Exploration for bottomless arches ("superspan," etc.), stiff-leg culverts supported on footings, and for box culverts is required to define footing and bottom slab support conditions. Drill at least two (2) borings for footing supported structures and box culverts. Drill additional borings on about 100 to 200 feet (30 to 60 meters) centers on long structures. More closely spaced borings may be needed where subsurface conditions are non-uniform, or to profile the surfaces of possible bearing layers such as rock or dense gravel.

The required footing depths will be dictated by scour potential as well as foundation loads and subsurface conditions. Borings and test pits should extend to depths below the anticipated footing bottom elevations equal to at least five (5) times the footing width or two (2) times the structure width for box culverts. For high fills or on compressible soils, the fill and/or structure weight may require deeper borings, as the fill weight (or structure weight) and underlying weaker/softer soils will control the settlement. All borings and test pits shall extend through weaker/softer soils encountered within the zone of influence of the overlying embankment and/or footing, and into underlying competent soil or rock. If rock is encountered at shallow depths (within the zone of influence of the fill or structure footings), extend at least two (2) borings 10 feet (3 meters) into the rock.

420.03 Laboratory Testing. Corrosion testing shall be performed at all culvert locations in accordance with Section 230.24.

SECTION 425.00 – SUBSURFACE INVESTIGATIONS FOR ROADWAYS INCLUDING CUTS AND EMBANKMENTS

425.01 Introduction. Investigations performed for roadways, including cuts and embankments, should be performed to develop recommendations and design criteria for pavements, slope angles, embankments, grade points, and drainage as well as to investigate the character of the material to be excavated. For high cuts and fills (20 feet (6 m) or higher), embankments on soft foundations and side hill embankments, more than a typical soils profile exploration is needed to obtain data to perform stability and settlement analyses.

The information which is required to evaluate cut slope or embankment stability varies relative to the material type. For soils, types, deposition features, consistency/apparent density, unit weight, variation, moisture contents, and other engineering properties are needed for analyzing cut slope or embankment stability. If rock is involved, the mineralogy, strength, bedding, and jointing (including joint orientation, weathering, roughness and infilling), etc. should be investigated.

425.02 Subsurface Investigation Scope. The field work for this subsurface investigation phase consists of evaluating the soils and rocks by means of auger borings, rotary drills, test pits, road cuts, etc. There is no definite rule to follow except that the subsurface conditions should be investigated at close enough intervals to obtain representative samples, and to determine the boundaries of each significant soil or rock type occurring on the project. For more specific guidance for subsurface investigations for roadways, see Section 425.04 below. Additionally, soil sampling shall be performed at all proposed culvert locations for subsequent pH and resistivity testing in accordance with Section 230.24.

425.03 Preliminary Study of Site Data. Prior to starting field work, the available existing literature should be reviewed to obtain general information useful in planning and organizing the subsurface investigation. Topographic maps, aerial photographs, geologic maps and county agricultural soil maps have been published for many sections of the state. A study of this information type, when available for the area in which the survey is to be made, will justify the time required for the study. It is important that the limitations of various map types be recognized. Some maps show considerable detail while others are of the reconnaissance type, and only show more general features.

It should be noted that each soil type may have a characteristic range in engineering properties, parent material, relief, permeability and vegetation. Each rock type generally will have distinctive strength, jointing, weathering patterns and permeability. Localized faulting, folding, shearing, secondary mineralization, chemical alteration, or joint orientation, weathering, roughness and infilling can significantly alter the basic characteristics of the rock mass. These criteria can be used to assist in the identification of the various soil and rock types and thus enable the investigator to subdivide the study area into various map units which reflect soil and rock conditions likely to require similar engineering treatment.

The soil and rock observed along the roads in the proposed highway vicinity should be studied, and changes in the soil profile or rock type and condition should be noted as they occur. These notes should include a complete description of each soil or rock type observed. A correlation of this information with the parent material types, the slope steepness range, the topographic position, the drainage conditions, and the land form or air photo soil pattern can be used to establish a system for the identification of different soil or rock types occurring in the area.

It may be desirable to prepare a preliminary strip map covering the area in which the road is to be located. In complex terrain, especially if adverse ground conditions exist, such a map will be useful in establishing the preliminary lines for location work. Usually such maps are made on an air photo base prepared from the parent material delineations obtained from geologic maps. The above information sources supplemented with limited ground reconnaissance should enable the investigator to prepare a reconnaissance map showing the distribution of the major soil and rock units likely to be encountered during the detailed investigation. In many instances, adverse ground conditions can be avoided by locating the highway through terrain which has more favorable anticipated subsurface conditions from the standpoint of current design practice. This map, if prepared on the proper scale, can later be converted into a detailed subsurface map by accurately locating all borings and test pits, and showing soil or rock boundaries determined during the subsequent detailed investigation made for the selected road location.

425.04 Site Exploration. The following guidelines should assist the investigator in preparing a detailed subsurface investigation for roadways. Modifications to the indicated guidelines may be required to handle special conditions which are not encountered in the typical subsurface investigation.

425.04.01 Boring and Test Pit Spacing. Borings and test pits should be spaced at a maximum of 200 feet (60 m) for erratic conditions and 500 feet (150 m) for uniform conditions, with at least one (1) boring or test pit taken in each separate landform. If the subsurface conditions are very erratic, this spacing may have to be as close as 50 ft. (15 m) to 100 ft. (30 m), depending on the length and width of the embankment. For cuts and fills over 20 feet (6 m) high and in side hill sections, a minimum of two (2) additional borings or test pits along a straight line perpendicular to the centerline should be drilled or dug to establish a geologic cross section for stability analysis. At least one (1) boring or test pit shall be taken at the highest point in roadway and bridge approach embankment fills, with at least one (1) additional boring or test pit at the embankment toe where stability problems are anticipated. Likewise, at least one (1) boring should be taken at the highest cut locations. One (1) boring or test pit should be located near the probable catch point in cuts, and at the grade point of cut/fill transitions. Additional borings or test pits may be needed up-slope from the catch point or down-slope from the toe in areas of potential instability.

Preliminary exploration by geophysical methods may reduce the required number of borings or test pits. This exploration type is particularly applicable where the material to be excavated is rocky, gravelly, or cemented, and gets denser or harder with depth. In this case, it may be desirable to accomplish only sufficient borings or test pits to obtain representative samples for testing, and to check the accuracy of the geophysical exploration results. However, be aware that underlying softer or weaker strata may not be detected by some geophysical methods.

425.04.02 Boring and Test Pit Depth. For proposed cuts in stable materials extend the borings and test pits to a minimum of 10 feet (3 m) below the proposed subgrade. For cuts in weak soils, extend borings and test pits below the proposed subgrade to firm materials or to a depth below the proposed subgrade equal to the proposed cut depth, whichever comes first.

Extend borings and test pits in embankment areas into firm, relatively incompressible material or to a depth of at least twice the embankment height below the existing ground surface if weak compressible materials persist at depth. In firm, stable foundation materials, borings and test pits need not penetrate to a depth greater than the embankment height. In all cases, borings and test pits in proposed embankment areas should be advanced to a depth of not less than 20 feet (6 meters), unless rock is encountered at a shallower depth.

425.04.03 Recording Subsurface Information. A complete and systematic record of all subsurface investigations should be prepared in accordance with Sections 440.00 and 450.00 for each subsurface investigation.

The boring or test pit record should indicate the location of seepage zone(s) or the position of free water if it occurs in the boring. The bedrock contact, and the nature and type of bedrock penetrated by the boring should also be recorded. Fracturing, jointing, mineralization, alteration (i.e. weathering) and RQD (Rock Quality Designation) information as described in Sections 440.00, 445.00 and 450.00 should be included in all rock descriptions.

425.04.04 Field Tests. Field tests, as described in Section 445.00 performed during roadway subsurface investigations, typically include Standard Penetration tests (SPT's) and Dynamic Cone Penetration (DCP) tests for soils, Rock Quality Designation (RQD) and point load tests for rocks.

425.04.05 Laboratory Tests. Representative soil and/or rock samples obtained during the subsurface investigation should be submitted for laboratory tests. The test types performed will depend on the expected material use and/or the anticipated loading from the proposed construction. For a soil layer ballast requirement determination, the laboratory tests may include the following: Moisture And Density

Relations Of Soils, Gradation, Atterberg Limits, and R-Value. Tests that are generally required for cut slope or embankment stability analyses are: Unit Weight, Moisture Content, Atterberg Limits, Unconfined Compressive Strength, Shear Strength, and Consolidation.

425.04.06 Soil Profile Mapping. The cut and embankment investigation results should be presented in the Phase II Soils Report and Soils Profile. Special investigations for individual cuts or embankments may be presented as an addendum or supplement to the Phase II Soils Report, or as a special Geotechnical Report. Addendum or supplemental reports should include, but not be limited to, boring (or test pit) logs, cross sections at analysis locations, special design requirements and details, and plan views showing borings (or test pits), limits of construction, and special feature locations such as drains. The Phase II Soils Report and Soils Profile requirements are presented in Section 230.00.

The data obtained from boring (or test pit) records and subsurface profile studies should be plotted on the Soils Profile sheet to assist in making design recommendations. The Soils Profile scale should be selected to adequately depict the information. Each significant layer encountered in the test borings (or test pits), and all surface features pertinent to the project design should be incorporated into the Soils Profile sheet as described in Section 230.00. Supplementary cross-sections should also be utilized where necessary to convey a clearer picture of the terrain and subsurface conditions as they relate to proposed cuts and fills.

Show boring (and test pit) logs and encountered subsurface conditions only at actual boring (or test pit) locations on the Soils Profile. Do not attempt to make a continuous profile by extending layers from one boring (or test pit) to another.

Where subsurface conditions are indicated by visible features or from previous explorations, an abbreviated exploration program may be appropriate. However, borings and/or test pits will still be needed to confirm the visible evidence or information from previous investigations.

425.04.07 Data Analysis. Recommendations for the engineering use of soil or rock should be based on physical properties, as determined from appropriate field and laboratory tests, engineering analyses, and environmental characteristics. In some instances, the known behavior of similar material based on experience from previous construction or during pavement behavior studies may be effectively used to appraise the engineering use of the material for design purposes.

425.04.08 Special Problems. The water table location, subsurface water flow magnitude, wetlands exploration, bedrock location and cut slope and fill foundation stability determination are often treated as special problems during the course of performing a highway subsurface investigation. The person conducting the investigation should be especially cognizant of these problems, however, and should be able to visualize their relationship to the proposed project design. Recognition of potential problems and gathering the right information during the subsurface investigation phase is very important.

The following are examples of problems often encountered in the field during subsurface investigations:

1. Water Table. If no trace of moisture is observed in the test pit or boring, it may be backfilled at once. But if water is found or indicated a piezometer or observation well should be installed, or the boring or test pit should be left open for 12 to 24 hours to allow the water to rise to its final level, so that this stable position can be recorded. When a boring or test pit indicates that the construction may be below the existing ground water table, special drainage may be required, and it is advisable to make a detailed study of the area. Where ground water is encountered, additional borings or test pits should be made nearby to check the magnitude and extent of the high ground water condition. All ground water information should be plotted on the Soils Profile.

Soil with a mottled color is often an indicator of areas which may have a fluctuating water table, especially if the mottling consists of gray and blue colorations interspersed with brown, yellow or rust colorations.

Certain types of vegetation are also indicators of high ground water conditions. The presence or absence of indicating vegetation can be used effectively to determine if seasonal high water table conditions are likely to occur in the area being investigated. Piezometers should be installed and water table elevations should be checked periodically if conditions warrant.

When ground water is encountered, a careful check of the surrounding area should be made to determine if any existing wells or springs in the proposed road section vicinity could be affected by the proposed construction.

2. Bedrock. Determination of the bedrock horizontal limits and surface elevation(s) usually requires a detailed site study. Sufficient borings or test pits should be made to obtain representative samples and to accurately define the bedrock contact occurring in all road cuts. Bedrock samples should be examined to determine the uniformity and nature of the underlying rock. In areas containing variable bedrock depths, it may be desirable to explore the area first by geophysical methods. The geophysical information can then be used to determine the most advantageous locations for subsequent depth to bedrock checking by drilling or test pitting, and to evaluate whether bedrock can be excavated by ripping or will require drilling and blasting. All rock outcrops, test pits or borings used to determine the depth to bedrock should be included on the Soils Profile drawings. See Sections 440.00, 445.00 and 450.00 for guidelines for describing and classifying bedrock.

SECTION 430.00 - SUBSURFACE INVESTIGATIONS FOR LANDSLIDES

430.01 Introduction. One of the most costly problems affecting the transportation system are landslides. Landslides are typically defined as the movement of a mass of rock, debris, or earth down a slope. Landslides can be triggered by human activities, such as road cut excavation or by natural events such as intense rainfall, earthquake shaking, volcanic eruption or stream erosion at the toe of slopes. In some areas, the natural slopes are subject to periodic slide development regardless of construction activity. Slides associated with highway construction may occur during the construction phase, or remain marginally stable for years until triggered by changes in physical or environmental factors (increased precipitation, blocked drainage, slope maintenance, subsequent construction activities, earthquakes, etc.).

Landslide investigations needed to develop preventative measures (if recognized during initial subsurface exploration) or corrective measures require diverse exploration and analysis methods.

Some potential or active slide masses defy theoretical approaches and, therefore, analyses rely mainly on experience and judgment, while others can be analyzed by established geotechnical methods.

430.02 Guidelines for Exploration.

430.02.01 Preliminary Reconnaissance. Review all available literature such as topographic maps, air photos, geologic reconnaissance reports, previous boring records, surface water and groundwater data before beginning a landslide field exploration. The District and Headquarters Materials personnel (or other geotechnical engineer and/or geologist in responsible charge of the work) should make a field review in order to develop an exploration program. The district will survey the area and make cross sections available to those responsible for the investigation.

Where slide movement is rapid and there is a high risk to the public, corrective action and/or exploration may have to be initiated based on the initial field reconnaissance and before survey and other background data are available.

430.02.02 Exploration. Examination of subsurface conditions must be made by borings and/or test pits. Boring and test pit locations must be referenced by centerline station and offset, and known elevations. The primary exploration purpose is to locate probable or actual failure zones. If this cannot be accomplished through borings, then open pits or instrumentation are needed.

Locate borings along a cross section to depict strata orientation, failure surface or zone location, and groundwater levels. This will require at least two (2) borings within the slide mass per cross section. Where the slide toe is not well defined, more than two (2) borings within the slide mass is desirable to define the failure plane or zone. The number of cross sections explored will depend on the extent and complexity of the problem. On active slides, if movement is too rapid to drill within the slide mass, locate borings above and below the active area(s). Borings beyond the slide flanks are sometimes needed to determine if the slide has grown in size.

Extend borings a minimum of 10 feet (3 m) below potential or active failure surfaces and into stable material.

NOTE: Some failure surfaces occur below the apparent rock surface and are difficult to detect. If the failure surface is not apparent, extend borings to a depth at which geometry indicates failure is unlikely. No hard and fast rule regarding boring location or depth applies to all conditions, but little opportunity exists to return to the site of an active slide for additional information. Experience indicates that the movement depth below the ground surface at the slide center is seldom greater than the failure zone width.

See Section 445.00 for applications of various sampling equipment and methods to perform the explorations.

430.02.03 Instrumentation. In addition to recovering samples for laboratory testing, exploratory borings are used to install instrumentation for monitoring slide movement and groundwater. Inclinometers installed in exploratory borings provide information on location of the failure surface and rate of movement. When installed in potentially unstable areas prior to construction, the inclinometers are used to detect movements early enough to initiate corrective action before major failures occur. Inclinometers can also function as groundwater monitoring wells.

At least two (2) inclinometers should be installed on a cross section within the slide mass. Inclinometers must extend a minimum of 10 feet (3 m) below the lowest failure surface and be socketed into firm material.

Piezometers are commonly used to monitor ground water levels and soil pore water pressures. Proper piezometer type selection should be evaluated carefully for each location, as the installation of some piezometers may be costly and they will be relied on to provide critical data.

430.03 Sampling and Field Testing. General guidelines for sampling and field testing are presented in Section 445.00.

The primary purpose of landslide explorations is to obtain undisturbed soil samples, especially in the failure surface area or zone for lab testing. Depending on the slide mass character, ring samples, Shelby tubes, or core borings may be most appropriate. Obtain continuous samples from the boring portion(s) through the failure zone to assure that the material in this zone is recovered.

NOTE: In rotary drilling using water, failure surface material will probably be washed out of core borings and lost. Therefore, this drilling method is not recommended for these investigation types. Continuous ring samples, piston samples, or pitcher barrel samples are more effective under these conditions.

430.04 Laboratory Testing. Soil samples obtained from landslide investigations are normally tested for unit weight, moisture content, Atterberg limits, and shear (peak and residual) strength. Rock core samples are normally tested for shear strength at natural fractures.

430.05 Exploration Record. Prepare record of boring, sampling, and field testing in accordance with Sections 440.00, 445.00 and 450.00. Indicate failure surface location(s) on the boring logs, if known.

430.06 Investigation Results. Present the investigation results in a special report, including topographic mapping, cross sections, analysis results, boring logs, and inclinometer and piezometric data. The report should address the subsurface conditions, and analysis methods and results. Corrective action recommendations should be presented along with alternative repair method comparisons.

SECTION 435.00 – SUBSURFACE INVESTIGATIONS FOR MISCELLANEOUS STRUCTURES, INCLUDING TRAFFIC SIGNAL, LIGHTING AND SIGN STRUCTURES, RETENTION PONDS, SAND SHEDS AND PAVEMENT REHABILITATION PROJECTS

435.01 Introduction. This section is intended for subsurface investigations for miscellaneous structures, including traffic signal and sign structures, such as Dynamic Message Sign (DMS), cantilever signs, sign or signal bridges, box structures, signal poles with mast arms longer than 55 feet (17 m), and high mast lighting structures. Additionally, this section addresses subsurface investigations for retention ponds, sand sheds and pavement rehabilitation projects.

Contact the Geotechnical Engineer at the Headquarters Materials Section for guidelines on subsurface investigations for miscellaneous structures that are not included in this section.

435.02 Exploration. Subsurface investigations for miscellaneous structures should be done by drilling test borings. However, shallow investigations, less than 15 feet (4.5 m) deep, can also be accomplished by digging test pits, if drilling test borings is not possible. Field tests, such as the Standard Penetration Test (SPT) or the Dynamic Cone Penetration (DCP) Test, should be performed when possible. These tests will help to determine soil type, estimate their relative density or consistency, and soil bearing capacity. Soil samples should be obtained during subsurface investigations for lab testing to determine basic soil properties, such as soil classification, moisture content, unit weight, shear strength, etc. Rock samples should also be taken where applicable.

As in any subsurface investigation, ground water should be observed and recorded if it was encountered during the investigation.

435.02.01 Traffic Signal and Sign Structures (Dynamic Message Signs, Cantilever Signs, Sign or Signal Bridges, Mast Arm Pole with Mast Arm Longer Than 55 feet, high mast lighting structures, Box Structures). Test borings or test pits shall be located at the proposed structure location, or as close to it as possible.

For drilled shaft foundations, borings shall extend to a minimum depth of 25 feet (7.5 m) or to bedrock, which ever is shallower. For spread footings, borings or test pits shall extend to a minimum depth of 15 feet (4.5 meters) below the proposed footing depth or bedrock, whichever is shallower. The boring or test pit depth should be increased as required for those cases where large overturning loads are anticipated or where poor ground conditions are encountered during the subsurface investigation.

435.02.02 Retention Ponds. For retention ponds with embankments less than 10 feet (3 m) high, a minimum of two (2) borings or test pits shall be excavated/drilled per 40,000 square feet (3700 m^2) of pond surface area. The minimum test pit/boring depth shall be 10 feet (3 m) below the deepest pond bottom elevation. For retention ponds with embankments greater than 10 feet (3 m) high, refer to Section 425.00 for subsurface investigation guidelines. Field permeability tests, such as Open End Borehole or Pumping tests, may be performed to determine the permeability of native soils. Sufficient additional exploration and materials testing shall also be accomplished to assess excavation difficulty and potential re-use of excavated material for embankment construction.

435.02.03 Sand Sheds. A typical sand shed is an open-wall structure, with an average size of about 60 feet by 120 feet (18 m by 36 m), and supported by individual columns located on the perimeter of the structure. In most cases the columns are founded on rectangular-shaped, spread footings. The spread footings are typically founded below the frost depth, which varies from about 2.5 to 4 feet (0.75 to 1.2 m), depending on the location. The proposed structure footprint should be located by survey methods before the subsurface investigation begins.

For typical size sand sheds, a minimum of four (4) test pits or soil borings, one (1) at each corner of the proposed structure footprint area, shall be excavated/drilled. Additional subsurface investigation should be accomplished along the perimeter of the proposed building footprint if the structure is significantly larger than typical, where erratic or poor subsurface (i.e. bearing) conditions are encountered during the subsurface investigation, or where bedrock is encountered at a depth of less than 5 feet (1.5 m).

Borings or test pits shall extend to a minimum depth of 10 feet (3 m) below the proposed footing bottom elevation or to bedrock, whichever is shallower.

435.02.04 Pavement Rehabilitation Projects. For pavement rehabilitation projects, core or drill through the existing roadway to a minimum depth of 5 feet (1.5 m), or as necessary to determine surface, base, and subbase thicknesses, and to field classify the subgrade soil along the project length. Borings should be drilled every 0.5 to 1.0 lane mile, depending on anticipated traffic loadings and the relative uniformity of subsurface conditions, based on a review of available subsurface information at the District Materials Section prior to developing the subsurface investigation plan. Additional borings should be drilled in those areas where the subgrade soils are erratic. An approved traffic control plan and a permit to work within the right-of-way are required from the District Traffic Section.

All existing culverts shall be inspected to assess maintenance and/or replacement needs, and soil samples shall also be obtained at all existing culvert locations to assess soil corrosivity potential for possible culvert replacement work that could be done either prior to or concurrently with the pavement rehabilitation work.

SECTION 440.00 - GUIDELINES FOR PREPARATION OF SUBSURFACE INVESTIGATION FIELD LOGS

440.01 General. This section contains general instructions for preparation of field logs on Form ITD-981, Boring/Test Pit Log (Figure 440.01.1 located at the end of Section 440.00). However, other boring/test pit log forms could be substituted by consultants, provided the same minimum information as required herein is clearly and logically presented. Soil description and identification as described herein

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is based on ASTM D 2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

The purpose of these instructions is to promote clarity and uniformity in logging soil and rock as they are encountered in the field. This work phase is very important and proper recording cannot be overemphasized. The log may be the only reference or information available to the geologist and geotechnical engineer for their use in providing design recommendations.

Subsurface investigations shall only be performed by experienced persons. If the person performing the subsurface investigation is not a Registered Professional Engineer or Geologist with experience performing subsurface investigations, then that person shall work under the direct supervision of the experienced, registered professional. All test pit and boring logs, and exploration descriptions shall be reviewed for completeness and accuracy by the registered professional in responsible charge of the work.

Boring and test pit logs shall provide a continuous profile of the exploration. Contacts between units or strata shall be indicated by dashed or solid lines, or other appropriate methods. Contacts may not be observed, but may be inferred by the results of the work. Lost core or other samples shall be indicated on the log.

440.02 Procedure.

440.02.01 Key No., Project No., and Project Name and Location. Obtain this information from the project data furnished by the district.

440.02.02 Boring/Test Pit No. On projects where there is more than one (1) type of exploration, such as borings and test pits, use the symbols described on Figure 440.02.02.1, Drill Hole/Test Pit Log Nomenclature, located at the end of Section 440.00. Each boring or excavation type under the same project should be numbered consecutively without regard to feature, location, or drilling dates.

440.02.03 Date and Sheet No. Show the date that drilling or test pit excavation was started and completed, and the total consecutive number of sheets used for that particular boring or test pit.

440.02.04 Collar/Ground Surface Elevation. Determine the collar elevation (ground surface elevation for test pits) from a survey reference point or by interpolation from a topographic map. Determine the elevation to the nearest 3 inches (75 mm), if practical.

440.02.05 Reference Point. Provide survey benchmark location and datum. If no survey benchmark is available, use a permanent object as a temporary benchmark that will not be removed or disturbed.

440.02.06 Technician/Geologist, Engineer and Driller. Provide the full names of all personnel performing subsurface investigations.

440.02.07 Location. Give a brief description of the boring or test pit location, including station and offset. Describe any deviation from planned boring or test pit locations, including reasons for deviations.

440.02.08 Water Level(s), Time(s). Ground water information (including the ground water table elevation) is one of the most important parts of the log. Try to determine what strata the water is coming from, including a flow rate estimate. The ground water information plays an important part in foundation, drainage and slope stability recommendations. Note the time required for the water level to stabilize in the boring or test pit, and if artesian conditions exist.

Ground water, if encountered, must be documented. Excuses for not determining the groundwater level, such as water or slurry was used during drilling and, therefore, the ground water level could not be determined, are not acceptable.

440.02.09 Drilling Method, Driving Weight, and Average Drop. Describe the type and size of drilling equipment. Show the driving weight and average drop height for the driving sampler. Also, hole diameter, rod size, whether split barrel sampler used liners, and whether liners were used or not, including any other pertinent information about the drilling process used should be noted here.

440.02.10 Termination Elevation. Indicate the boring/test pit termination elevation in feet (meters).

440.02.11 Sample Type and Number. Report the sample type in accordance with Drill Hole/Test Pit Log Nomenclature (Figure 440.02.02.1, located at the end of Section 440.00). The numbering of each sample type should be consecutive with increasing depth (e.g., the second ring sample will be RS-2), even though many samples of other types have been obtained above this point. Note all unsuccessful sampling attempts.

440.02.12 Sample Depth. Indicate the sample top and bottom depth.

440.02.13 Resistance. Record the number of blows, if driven. If the sampler is pushed part way, record the depth pushed and required hydraulic pressure for pushing, and the number of blows required to complete the sample. If pushed only, this should be noted along with the hydraulic pressure required to push the sampler. When performing Standard Penetration Tests (SPT's), record the number of blows for each 6-inch (150-mm) increment driven, and indicate by putting "N" under Sample Type.

440.02.14 Moisture. Indicate the soil moisture as follows:

- Dry (D)- No sign of water, dusty, soil dry to touch,
- Moist (M)- No visible sign of water, soil is damp to touch,
- Wet (W)- Visible signs of water, soil wet to touch, granular soils may exhibit some free water when disturbed.

440.02.15 Apparent Density/Consistency. Depends upon the soil type. A different system is used for each of the following soil types. See Section 450.00 Guidelines for Soil and Rock Classification for further details.

Coarse-Grained Soils

For coarse-grained (cohesionless) soils classified as GW, GP, GM, GC, SW, SP, SM, SC (i.e. Sands and Gravels), describe relative density based on the SPT N-values.

Coarse grain soil apparent density can be estimated in the field as shown in the following table:

Descriptive Term (Relative Density, %)	SPT N-value (Number of Blows Per Foot)	Remarks
Very Loose (0 to 15)	0 to 4	
Loose (16 to 35)	5 to 10	Easily penetrated with a ½-inch (13-mm) rebar pushed by hand
Medium Dense (36 to 65)	11 to 30	Easily penetrated with a ½-inch (13-mm) rebar driven with a 5-pound (2.3-kg) hammer
Dense (66 to 85)	31 to 50	Penetrates 1 foot (300 mm) with a ½-inch rebar driven with a 5-pound (2.3-kg) hammer
Very Dense (86 to 100)	>50	Penetrates only a few inches with a ½-inch (13-mm) rebar driven with a 5-pound (2.3-kg) hammer

Fine-Grained Soils

For fine-grained (cohesive) soils classified as ML, CL, OL, MH, CH, OH, PT (i.e. Silts and Clays), report soil consistency based on SPT N-values, Torvane or Pocket Penetrometer readings. Test values should be recorded in the Remarks column when these tests are performed.

Fine grain soil consistency can be estimated in the field as follows:

Fine Grain Soil Consistency	SPT N-value (No. of Blows Per Foot)	Unconfined Compressive strength* Tons Per Square Foot (kPa)	Remarks
Very Soft	<2	<0.25 (<24)	Squeezes between fingers when molded
Soft	2 to <4	0.25 to <0.50 (24 to <48)	Easily molded with fingers
Firm	4 to <8	0.50 to <1.00 (48 to <96)	Can be molded with strong finger pressure
Stiff	8 to <15	1.00 to <2.00 (96 to <190)	Indents with hard thumb pressure
Very Stiff	15 to 30	2.00 to 4.00 (190 to 380)	Readily indents with thumbnail
Hard	>30	>4.00 (>380)	Indented with difficulty by thumbnail

* Undrained shear strength is equal to one half (1/2) of the unconfined compressive strength.

440.02.16 Color. Describe the colors observed in the moist condition in accordance with Figure 440.02.16.1 (located at the end of Section 440.00) General Instructions in Using Color to Describe Soils and Rock.

440.02.17 Description. Describe the soil encountered from the recovered samples. The field soil classification should be made in accordance with ASTM D 2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), and include group names and group symbols. Dual classification symbols may be put on the field logs, but their use should be minimized where possible. Terms like SILTY, CLAYEY SAND and SANDY, CLAYEY SILT and CLAYEY, SILTY, GRAVELLY SAND, etc. are not in accordance with ASTM D 2488 and should not be used. The soil description methodology is shown on Figures 440.02.17.1A and 440.02.17.1B, located at the end of Section 440.00

A close approximation to the final soil description can be ascertained in the field by visual methods and simple field tests. For coarse-grained soils, the description is made by estimating grain sizes. The soil should be further described by indicating any secondary constituents observed. In this case, terms such as “with silt” or “with sand” would be used. Add the grain size description, such as well graded or poorly graded, and fine, medium, or coarse grained. For grain size, the following information serves as a guide:

- Boulder- Greater than 12 inch (300 mm) diameter,
- Cobble- Diameter is between 3 and 12 inches (75 to 300 mm),
- Coarse Gravel- Diameter is between ¾ and 3 inches (19 to 75 mm),
- Fine Gravel- Diameter is between 0.2 and ¾ inches (4.75 to 19 mm),
- Sand- Diameter is between 0.003 and 0.2 inches (No. 200 to No. 4 sieves) (75 µm and 4.75 mm),
- Silt and Clay- Individual grains (i.e. passing the No. 200 sieve) can not be seen with the naked eye.

The terms "cobble" and "boulder" are intended to apply to sub-rounded or rounded pieces of rock. Where angular or sub-angular rock fragments are encountered, use the term "rock fragment" and indicate the size and angularity. Where rubble is encountered, indicate the type and the size of the fragment.

The soil unit percentages composed of larger than gravel-sized particles (e.g. cobbles and boulders) shall be estimated on a volume basis per ASTM D 2488, and the percentages, and maximum particle size shall be reported on the boring or test pit log. This information shall also be presented on the Soil Profile in the Phase II Report.

For fine-grained soils, the simple tests for reaction to hydrochloric acid (HCl), dilatancy, dry strength, toughness, and plasticity are sometimes required for proper description. A summary of these methods are described below and in Figure 440.02.17.2, located at the end of Section 440.00.

Based on correlations and laboratory tests, the following simple field identification tests can be used to estimate the degree of plasticity of fine-grained soils.

<ins>Shaking (Dilatancy) Test:</ins> Water is dropped or sprayed on a part of fine-grained soil, it is then mixed and held in the palm of the hand until it shows a wet surface appearance when shaken or bounced lightly in the hand or a sticky nature when touched. The test involves lightly squeezing the soil pat between the thumb and forefinger and releasing it alternatively to observe its reaction and the speed of the response. Soils which are predominantly silty (non-plastic to low plasticity) will show a dull dry surface upon squeezing and a glassy wet surface immediately upon releasing of the pressure. With increasing fineness (plasticity) and the related decreasing dilatancy, this phenomenon becomes less and less pronounced.

Dry Strength Test: A portion of the sample is allowed to dry out and a fragment of the dried soil is pressed between the fingers. Fragments which cannot be crumbled or broken are characteristic of clays with high plasticity. Fragments which can be disintegrated with gentle finger pressure are characteristic of silty materials of low plasticity. Thus, materials with great dry strength are clays of high plasticity and those with little dry strength are predominantly silts.

Thread Test: (After Burmister, 1970). Moisture is added or worked out of a small ball (about 1.5 inches (38 mm) in diameter) and the ball kneaded until its consistency approaches medium stiff to stiff (compressive strength of about 15 psi (100 kPa)), it breaks, or crumbles. A thread is then rolled out to the smallest diameter possible before disintegration. The smaller the thread achieved, the higher the plasticity of the soil. Fine-grained soils of high plasticity will have threads smaller than 1/8 inch (3 mm) in diameter. Soils with low plasticity will have threads larger than 1/8 inch (3 mm) in diameter.

Smear Test: A fragment of soil smeared between the thumb and forefinger or drawn across the thumbnail will, by the smoothness and sheen of the smear surface, indicate the plasticity of the soil. A soil of low plasticity will exhibit a rough textured, dull smear while a soil of high plasticity will exhibit a slick, waxy smear surface.

Add an additional description of the materials, such as organic, micaceous, desiccated, visibly porous, etc. when observed. Indicate if the materials have shiny surfaces, or if salt, alkali deposits or calcium carbonate are present.

Calcium carbonate cementation should be field classified as follows:

- Weak- Crumbles or breaks with handling or little finger pressure,
- Moderate- Crumbles or breaks with considerable finger pressure,
- Strong- Will not crumble or break with finger pressure.

Layered Soils

Soils of different types can be found in repeating layers of various thicknesses. It is important that all such formations and their thicknesses are noted. Each layer is described as if it is a non-layered soil using the sequence for soil descriptions discussed above. The thickness and shape of layers and the geological type of layering are noted using the descriptive terms presented in the following table:

Type of Layer	Thickness, inches (mm)	Occurrence
Parting	<0.06 (<1.5)	
Seam	0.4 to 0.06 (10 to 1.5)	
Layer	12 to 0.4 (305 to 10)	
Stratum	>12 (>305)	
Pocket		Small erratic deposit
Lens		Lenticular deposit
Varved (also layered)		Alternating seams or layers of silt and/or clay and sometimes fine sand
Occasional		One (1) or less per 12 inches (305 mm) of thickness or laboratory sample inspected
Frequent		More than one (1) per 12 inches (305 mm) of thickness or laboratory sample inspected

Place the thickness designation before the type of layer, or at the end of each description and in parentheses, whichever is more appropriate.

Examples of descriptions for layered soils are:

- Medium stiff, moist to wet 0.2 to 0.8 inches (5 to 20 mm) interbedded seams and layers of: gray, medium plastic, silty CLAY (CL); and light gray, low plasticity SILT (ML); (Alluvium).
- Soft, moist to wet, varved layers of: gray-brown, high plasticity CLAY (CH) 0.2 to 0.8 inches (5 to 20 mm); and nonplastic SILT, with trace fine sand (ML) 0.4 to 0.6 inches (10 to 15 mm); (Alluvium).

It is also proper to add the geologic description (such as alluvium, tallus, colluvium, or weathered rock).

Rock Description

Rock conditions shall be evaluated and descriptions developed under the direction and responsible charge of a Professional Geologist or Professional Engineer Registered in Idaho (with experience and qualifications as appropriate to the project and setting) as described below, and as described in Sections 445.00 and 450.00. Describe the physical condition of the rock, including identification, width, spacing, infilling and roughness of discontinuities, degree of weathering, presence or absence of vesicles, existence of slickensides, etc. Describe whether discontinuities are filled or unfilled, including the composition of the infill material. Describe whether fractures are natural or are mechanical fractures caused during the drilling or core recovery process. Describe the lithology of the bedrock by its common geological name, such as siltstone, basalt, granite, etc. Core run length, percentage of core recovery, and RQD (Rock Quality Designation) must be recorded for each rock core.

Rock Weathering and Alteration

Weathering as defined here is due to physical disintegration of the minerals in the rock by atmospheric processes while alteration is defined here as due to geothermal processes. Terms and abbreviations used to describe weathering or alteration are presented in the following table:

Description	Recognition
Residual Soil	Original rock minerals have been entirely weathered to secondary minerals, and the original rock fabric is not apparent; material can be easily broken by hand.
Completely Weathered/Altered	Original rock minerals have been almost entirely weathered to secondary minerals, although original rock fabric may be intact; material can be granulated by hand.
Highly Weathered/Altered	More than half of the rock has been weathered so that a minimum 2-inch-diameter sample can be broken readily by hand across the rock fabric.
Moderately Weathered/Altered	Rock is discolored and noticeably weakened, but less than half is weathered; a minimum 2-inch-diameter sample cannot be broken readily by hand across the rock fabric.
Slightly Weathered/Altered	Rock is slightly discolored, but not noticeably lower in strength than fresh rock.
Fresh	Rock shows no discoloration, loss of strength, or other effects of weathering/alteration.

Discontinuity Spacing

Rock discontinuity spacing descriptions are presented in the following table.

Discontinuity Spacing	Description
>10 feet (>3 m)	Very Widely Spaced
3 feet to 10 feet (1 to 3 m)	Widely Spaced
1 foot to 3 feet (0.3 to 1 m)	Moderately Spaced
0.3 feet to 1 Foot (100 to 300 mm)	Closely Spaced
<0.3 feet (<100 mm)	Very Closely Spaced

Stratigraphic Boundaries

Stratigraphic (contacts) boundaries should be depicted on the test pit or boring logs with solid lines to separate the various soil and/or rock layers, or with dashed or wavy lines where the contact is inferred or gradational. Soil classifications, including layer descriptions and stratigraphic boundaries should also identify existing fill, topsoil, pavement system layers, etc. if encountered.

440.02.18 Group Symbol. Assign the group symbol in accordance with ASTM D 2488, (Figures 440.02.17.1A and 440.02.17.1B located at the end of Section 440.00).

440.02.19 Remarks. Indicate the ground surface condition such as smooth, rough, vegetated, etc. Also use this column to add anything pertinent, such as information on ground water and drilling. Indicate the relative drilling ease or difficulty (or other drilling information such as down time, clean hole, raveling, or caving). Indicate the presence of any organic or unusual odors, such as petroleum product, chemical, etc. that are encountered.

Note: sample recovery here in inches (mm). For example, if you have pushed or driven a sample 1 foot (300 mm) and recover only 6 inches (150 mm), this is important. If you observe that the sample has been disturbed, this should be noted.

Drilling fluid loss during boring advancement can be indicative of the presence of open joints, fracture zones or voids in the rock mass being drilled. Therefore, the fluid loss volumes and the intervals over which they occur should be recorded. For example, "no fluid loss" means that no fluid was lost except through spillage and filling the hole. "Partial fluid loss" means that a return was achieved, but the amount of return was significantly less than the amount being pumped in. "Complete fluid loss" means that no fluid returned to the surface during the pumping operation. A combination of the field personnel and the driller opinions on this matter can result in the best estimate of both how much fluid loss has occurred and why it has occurred.

Figure 440.01.1

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Field Boring/Test Pit Log

Sheet _____ of _____

See Section 440.02.13 of the Materials Manual for instructions on filling out this form.

Key Number	Project Number	Project Name and Location			
Boring/Test Pit No.	Boring/Test Pit Location		Boring/Test Pit Reference Point		
Collar/Ground Surface Elevation	Termination Elevation	Water Level Elevation	After (hours or days)	Drilling Start Date	Drilling End Date
District or Drilling Company	Driller's Name	Geologist/Technician's Name	Drilling/Excavation Method	Driving Wt. and Avg. Drop	

Depth – ft (m)	Sample			Resistance or SPT Blows per 6 inches (150mm)	Moisture	Apparent Density or Consistency	Color	Description	Group Symbol	Remarks
	Type	Number	Depth – ft (m)							
0										

Figure 440.02.02.1 – Drill Hole/Test Pit Log Nomenclature

DDH	=	Diamond Drill Hole
AH	=	Auger Hole
HAH	=	Hand Auger Hole
RDH(W)	=	Rotary Drill Hole (Water)
RDH(A)	=	Rotary Drill Hole (Air)
BH	=	Backhoe Hole
TP	=	Trench or Pit
CE	=	Collar Elevation of Drill Hole
VS	=	Vane Shear Test
SS	=	Standard Split Spoon Sample
RS	=	Ring Sample
BK	=	Bulk Sample
TW	=	Thin Wall Shelby
N	=	Standard Penetration Test Result
CR	=	Core Recovery
NCR	=	No Core Recovery
CS	=	Continuous Sample
RQD	=	Rock Quality Designation
PL	=	Plastic Limit
LL	=	Liquid Limit
PI	=	Plasticity Index

Figure 440.02.16.1 – General Instructions In Using Color To Describe Soil And Rock

Listed in parentheses after each color is an abbreviation that may be used on field logs. The abbreviations in brackets may be used when typing. However, abbreviate only when necessary.

White	(w.)	[wh.]	
Yellow	(y.)	[yell.)	
Orange	(o.)	[or.]	
Red	(r.)	[rd.]	Colors may be combined and color or combination may be modified by the adjectives light (lt.) or dark (dk.).
Brown	(br.)	[brn.]	
Green	(gn.)	[grn.]	
Blue	(bl.)	[bl.]	
Gray	(gr.)	[gr.]	
Black	(blk.)	[blk.]	

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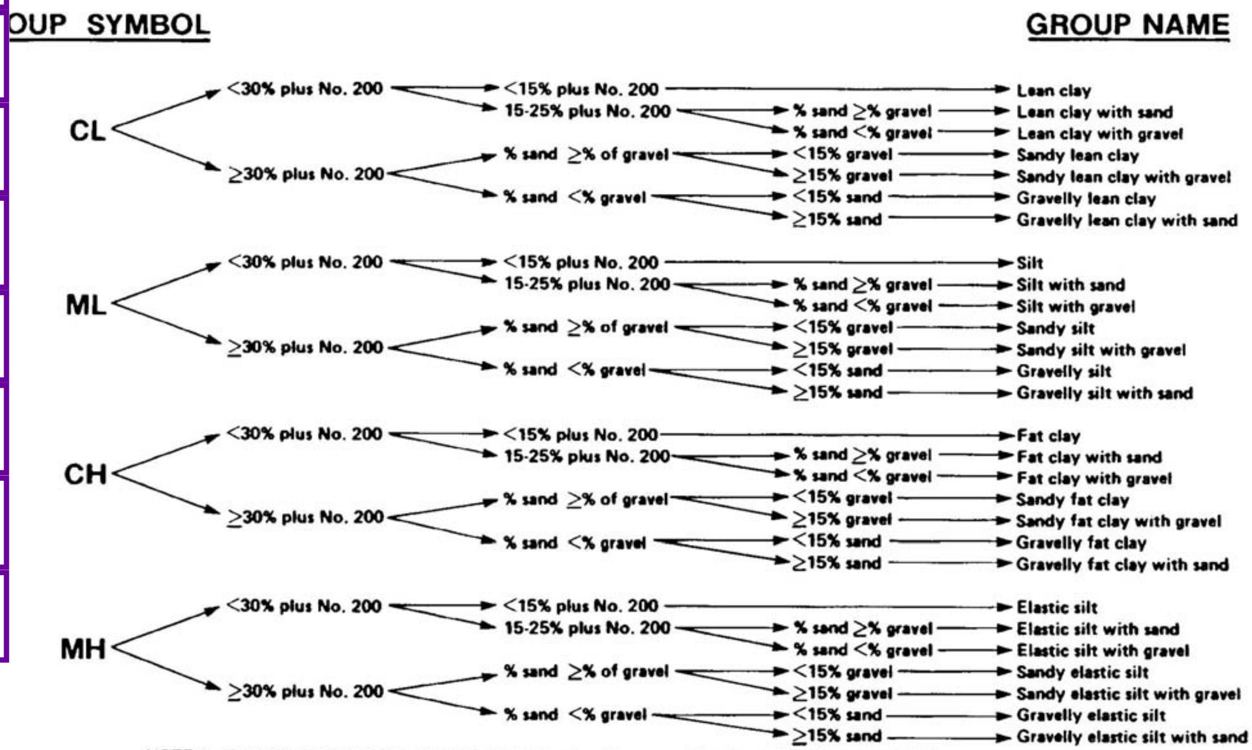
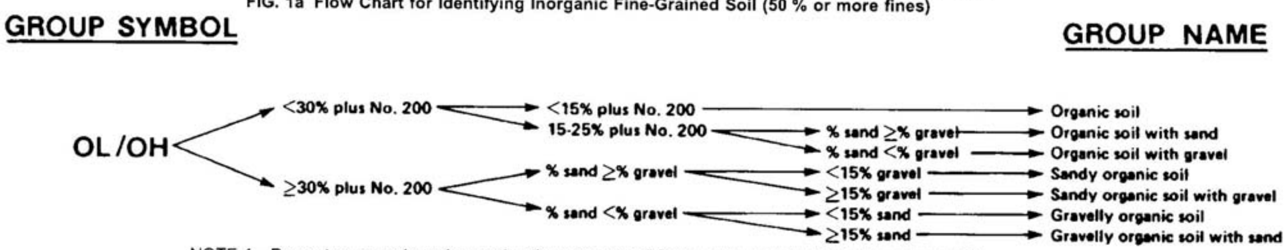
Figure 440.02.17.1A



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

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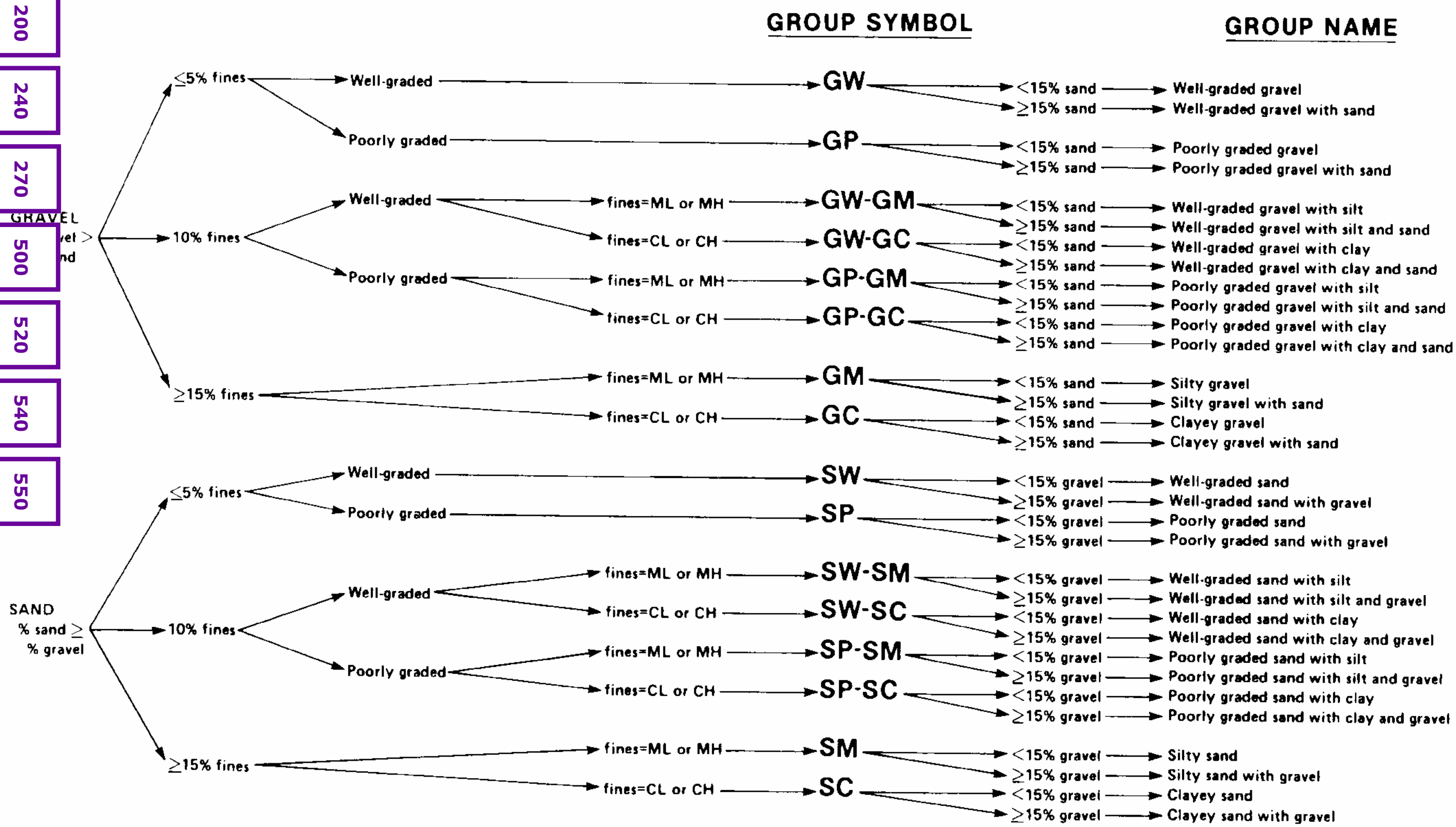
Figure 440.02.17.1B



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

Figure 440.02.17.2

A) Criteria for Describing the Reaction with HCl:

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

B) Criteria for Describing Dry Strength:

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.
High	The dry specimen cannot be broken with finger pressure. The specimen breaks into pieces between the thumb and a hard surface.
Very High	The dry specimen cannot be broken between the thumb and a hard surface.

C) Criteria for Describing Dilatancy:

Description	Criteria
None	No visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

D) Criteria for Describing Toughness:

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread near the plastic limit. The thread and the lump have very high stiffness.

Figure 440.02.17.2 (Continued)

E) Criteria for Describing Plasticity:

Description	**Criteria**
Non-plastic	A 1/8-inch (3 mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

F) Identification of inorganic Fine-Grained Soils from Manual Tests:

USCS Soil Symbol	**Dry Strength**	**Dilatancy**	**Toughness**
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

SECTION 445.00 - GUIDELINES FOR SAMPLING AND FIELD TESTING

445.01 General. Materials encountered during subsurface explorations are sampled in several ways; e.g., continuous samples from augers or special samplers, bag samples from auger borings or test pits, cuttings from rotary borings, Standard Penetration Test (SPT) samples, split barrel ring samples, thin-wall Shelby tube samples, or coring. Each is suited to particular materials or a specific purpose. Undisturbed samples suitable for laboratory consolidation and strength tests are primarily recovered from fine-grained soils (silts and clays) using split barrel ring samplers or thin-wall Shelby tubes. The split barrel ring sampler provides lower quality samples, but may be used to obtain adequate samples for strength testing in sands, silts, and non-sensitive clays. Samples of sandy soils for consolidation testing are usually obtained using the split barrel ring sampler. Hard or cemented soils and rock are typically sampled using a pitcher barrel or diamond core barrel. Only double- or triple-tube, NQ-size or larger, diamond core barrels should be used for rock coring. Triple tube core barrels are recommended.

All sampling, field testing, and sample preservation, transport and storage shall be done in accordance with the applicable test method(s) as referenced in Section 455.00. All samples shall have a unique identification which shall include as a minimum: project number, key number, test pit/boring number, sample number, sample depth, sampling date. All samples brought to the Headquarters Materials Lab shall be accompanied by a completed ITD Form 1044. Undocumented samples will not be processed and may be discarded.

In all cases where little or no material is recovered when sampling in a test boring, a second attempt should always be made to obtain the sample after appropriate modifications are made to the drilling and/or sampling method. This may require modification of the sampling tool or drilling a second boring to the same depth to obtain representative samples of important soil layers. If the second attempt is made in the same boring, then the hole should be cleaned out to undisturbed material before the second sample is attempted.

As a minimum, a representative, 75-lb soil sample should be obtained from each soil layer from either an exposed back slope or a test pit during the detailed investigation phase. A sufficient number of samples should be taken to establish the full range of both physical and engineering properties for each soil layer. For cuts and fills, undisturbed soil samples in critical layers should also be obtained for testing and stability analyses. Particular attention should be paid to sampling representative soils that will form the subgrade. R-value samples should be provided from all soil horizons that will exist at the proposed pavement subgrade, or that will come from cuts or potential borrow sources that will provide embankment material at the proposed pavement subgrade.

Samples of each potential embankment or subgrade soil unit should be collected for moisture-density relationship determination. In-place density and moisture content should also be determined for each soil unit where possible by either nuclear or other volumetric methods.

Geologic mapping of bedrock joint systems, shear planes, weathered zones and other areas of potential weakness will yield meaningful information for the design of roadway cuts or fills. The method used will vary with the particular project or setting, and with the type or condition of material encountered.

Information regarding the present topography and landform, as well as dimensions of the proposed structure or embankment, should be noted. This, plus the estimated unit weight of a proposed embankment, should be recorded and the information supplied (as applicable) to the Headquarters Materials Section with submitted undisturbed samples for testing.

Subsurface investigations should not be started until all required permits, and environmental and cultural clearances have been obtained.

445.02 Utility Locate. A utility locate should be requested by calling the appropriate one-call center for all sites a minmum of 48 business hours before beginning any subsurface investigation. The state or engineering consultant can be held responsible for all direct and consequential damages if a utility locate is not requested and a utility line is damaged; or if the request is made and a correctly located utility line is damaged anyway. However, liability for damages may not apply in cases where the utility line is not correctly located. Therefore, if at any time a utility line is encountered and damaged, field personnel should immediately verify whether or not the utility line was correctly located. This information should be forwarded to the district and be made a part of the project file.

For District 1 all utility locate requests should be made to Password. Separate toll-free phone numbers for the five counties in District 1 are provided as follows: Bonner and Boundary (1-800-626-4950), Benewah and Shoshone (1-800-398-3285), Kootenai (1-800-428-4950). For all other districts, utility locate requests should be made to Digline by calling 1-800-342-1585.

The one-call center will then contact all <u>member</u> utilities who have facilities in the vicinity of the project site. The one-call center does not contact non-member utility companies. ITD is not currently a member of any one-call center. Therefore, other means should be used to locate subsurface installations owned by ITD. Field personnel should review the utilities that will be contacted by the one-call center and determine if other utilities should be directly contacted which may not be one-call center members. Examples of other non-members include municipal water and sewer agencies, and irrigation companies.

Before a utility locate request is completed, field personnel should record the following information and place it in the project file:

- One-call center ticket number,
- Name of the utility coordinator taking the call,
- Date and time when the utility locate will be complete,
- Utilities or other entities who will be contacted.

In those cases where the site location is difficult to describe over the phone or where the site geometry is complicated, field personnel have the option of arranging for a utility meet through the one-call center. However, only a limited number of time slots are available for utility meets, so these may need to be arranged more than 48 business hours in advance of field work. All suspected non-member utilities should also be contacted directly by field personnel when utility meets are being arranged. The utility meet is also an efficient way to accomplish a utility locate in the event that inclement weather (which could cover or otherwise obscure utility markings) is anticipated before the field work is planned to begin.

In the event the field work is anticipated to be accomplshed during the time of the year when frequent inclement weather is expected, other markings, such as colored flags, should be used to mark utility locations. Field personnel should also always insist that the various utility representatives either directly mark the utility location, or leave a mark which indicates the site is clear. Field personnel should not assume a site is clear unless this is communicated directly by a utility representative. Arrangements should be made beforehand for all “clear” paint marks to be left at the same location at the site, so they can be easily (and quickly) found.

If a utility line is encountered or damaged, field personnel should immediately call the effected utility company, so the line can be inspected and repaired as soon as possible. The district should also be notified as soon as possible. All particulars regarding the incident should be written down, and this information placed in the project file.

Additional information regarding onsite utilities and utility locate requests can be found in the "Guide For Utility Management" publshed by ITD.

445.03 Field Sampling.

445.03.01 Soil Sampling. The following minimum information should be taken in the field and transmitted with the samples where appropriate:

- Boring/test pit project identification and date.
- Boring/test pit location, including centerline offset distance.
- Boring/test pit number.
- Collar or ground surface elevation.
- Boring/test pit log.
- Sample location/depth.
- Sample type and number
- SPT blow count or other sampler advancement method
- Sample recovery
- Water table or artesian elevation data.

The dimensions of all proposed structures, embankments, etc., if available, should also be provided.

Standard Penetration Tests (SPT) and other disturbed samples should be taken at 5-foot (1.5–meter) intervals or less, and at all changes in materials. However, the sampling interval should be reduced where critical structures, heavy concentrated loads or highly variable soil conditions are anticipated. Shelby tube or ring samples should be taken at minimum 5-foot (1.5 m) intervals in at least one (1) boring in soft or sensitive soils where consolidation and strength data are needed. Undisturbed samples should be obtained from more than one (1) boring where possible. Testable samples should be concentrated in the depth interval between zero and five (5) times the estimated width of the spread footing below footing subgrade elevation, and from the bottom of estimated pile cap elevation to a minimum of 20 feet (6 meters) below anticipated pile tip elevation. Samples should also be obtained from the ground surface to a minimum of 10 feet (3 meters) below the bottom of proposed cuts, and to a minimum depth below subgrade elevation of half the proposed embankment height for embankment exploration.

Undisturbed samples should be taken only in soils that are reasonably free of gravel or rock fragments and are of a consistency that will cause the sample to remain in the tubes. Immediately on surfacing the sample, it must be sealed and packed to minimize loss of moisture and sample disturbance, including freezing. These samples must then be taken to the laboratory for determination of pertinent engineering properties from tests such as direct and triaxial shear, consolidation, and permeability. See Idaho T62 and ASTM Test D4220 for instructions outlining the procedure for taking, preserving and transporting of undisturbed samples. Undisturbed samples shall not be transported to the laboratory via common carrier.

As a minimum, the depth to ground water and the presence of artesian conditions should be recorded both at the time water is first encountered and after the water level has stabilized, unless a piezometer or observation well is planned to be installed at the boring or test pit location. All ground water level determination and monitoring well installation shall be accomplished in accordance with ASTM D4750 and D5092, respectively. The date and time of all ground water observations should be recorded.

445.03.02 Rock Sampling. Rock cores should be taken for rock classification, percent recovery, Rock Quality Designation (RQD) determination and unconfined compressive strength testing. The core recovery is the length of rock core recovered from a core run, and the recovery ratio (or percent recovery) is the ratio of the length of core recovered to the total length of the core drilled on a given run, expressed as either a fraction or a percentage. Core length should be measured along the core centerline. When the recovery is less than the length of the core run, the non-recovered section should be assumed to be at the end of the run unless there is reason to suspect otherwise (e.g., weathered zone, drop of rods, plugging during drilling, loss of fluid, and rolled or recut pieces of core). Non-recovery should be marked as NCR (no core recovery) on the boring log, and entries should not be made for bedding, fracturing, or weathering in that interval.

Recoveries greater than 100 percent may occur if core that was not recovered during a previous run is subsequently recovered in a later run. These should be recorded as such; adjustments to data should not be made in the field.

<u>Core Handling and Labeling</u>

Rock cores from geotechnical explorations should be stored in structurally sound core boxes made of either corrugated plastic, corrugated, waxed, heavy cardboard, or wood as approved by the District Geologist or Materials Engineer, since long-term storage at the district may be required. All core boxes shall be provided with a proper lid or cover. The lid shall be secured by heavy rubber bands or other means acceptable to the district.

Cores should be handled carefully during transfer from barrel to box to preserve mating across fractures and fracture-filling materials, and to make sure that the core is placed in the box in the same sequence as it came out of the barrel. Any breaks that occur as a result of the drilling process, or during or after the transfer from barrel to box should be refitted and marked with three (3) short parallel lines across the fracture trace with a black permanent marker to indicate a mechanical break. Breaks made to fit the core into the core box and breaks made to examine an inner core surface should be marked as such. These deliberate breaks should be avoided unless absolutely necessary.

Cores should be placed in the boxes from left to right, top to bottom. The top and bottom core depths and each noticeable gap in the formation should be marked by a clearly labeled wooden spacer block.

If a core run has less than 100 percent core recovery, a wooden spacer block should be placed in the core box at the core loss depth. The core loss interval, if known, or length of core loss should be marked on the spacer block with a black permanent marker.

All rock core should be photographed in the wet condition as soon as it is placed in the core box. A label should be included in the photo to identify the boring, and the core depth and depth interval. A tape measure or ruler should also be included in the photo to provide scale. All photographs should be made under similar lighting conditions, and the lighting method should be compatible with the film type used.

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The core box labels should be completed using an indelible black marking pen. The core box lid should have identical markings both inside and out, and both exterior ends of the box should be marked.

For angled borings, depths marked on core boxes and boring logs should be those measured along the boring axis. The angle and orientation of the boring should be noted on the core box and the boring log.

Care and Preservation of Rock Samples

A detailed discussion of sample preservation and transportation is presented in ASTM D 5079. Four (4) levels of sample protection are identified:

- Routine care
- Special care
- Soil-like care
- Critical care

Most geotechnical explorations will require routine care in placing rock core in core boxes.

Special care is considered appropriate if the rock core moisture state (especially for shale, claystone and siltstone) and/or the corresponding rock core properties may be adversely affected by changes. This same procedure can also apply if it is important to maintain fluids other than water in the sample. Critical care is needed to protect samples against shock and vibration or variations in temperature, or both. For soil-like core, samples should be treated as indicated in ASTM D 4220. Rock core samples shall not be transported to the laboratory via common carrier.

445.03.03 Sampling Methods Summary. The following table indicates the recommended applications for available sampling methods. References relating to exploration and sampling are listed in Section 455.00, References.

Sample Type	Applicable Tests	Appropriate Soil Type
Bulk or Bag	Classification, pavement design (i.e. R-value), compaction (i.e. moisture density relationship), remolded strength, grain size analyses	All
Cuttings	Visual description	All
Standard Penetration	Classification, moisture	All
Ring Sample*	Classification, moisture, density, strength and consolidation**	All except gravels
Shelby Tube and Piston Samples	Classification, moisture, density, strength and consolidation	Fine grained soils (i.e. silts and clays)
Pitcher or Soils Core Barrel	Classification, moisture, density, strength	Stiff to hard silts and clays, cemented soils, soft rock
Diamond Core	Density, strength, mineralogy	Rock and some hard or strongly cemented soils

* May be driven like a standard penetration test in dense or stiff soils.
** Primarily in sandy soils. Also satisfactory for strength tests in non-sensitive and very stiff clays. Not suitable in soft silts and clays or layered clays.

445.04 Field Testing.

445.04.01 Field Testing for Soils. Field tests are performed to provide in situ strength data, water levels, and estimates of permeability. They can also reduce the number of borings needed or rapidly explore conditions between borings. Standard Penetration Tests (SPT), Field Vane Shear Tests, and Cone Penetrometer (Dutch Cone) Tests (CPT) are the primary methods available to develop in situ strength data. Pressuremeter or dilatometer equipment can also be obtained or contracted in special cases.

The Dutch Cone (CPT), Electric Cone Penetrometer (ECPT) with or without pore pressure measurements, solid cone penetrometer, and geophysical methods such as seismic refraction are the primary recommended field tests available for extending information between borings.

The Standard Penetration Test (SPT) should be performed to estimate the relative density and bearing capacity of cohesionless soils, and to give an indication of the consistency and bearing capacity of cohesive soils. SPT work should be performed with calibrated automatic hammer systems. The relative density is a guide for estimating the bearing capacity and settlement for shallow footings, and resistance to penetration and bearing capacity for piles. Disturbed soil samples are recovered from the SPT sampler for visual classification and index testing such as moisture content determination, Atterberg Limits, and grain size tests.

It should be clearly stated in the boring logs wherever non-standard SPT tests are done, such as when blow counts are from other than a standard, 2-inch (50-mm)-outside-diameter, split-spoon sampler. In these cases, the blow counts obtained from non-standard tests shall be converted to equivalent blow counts for the Standard Penetration Test. Additionally, a variety of other factors can have a significant effect on the resulting N-value as follows:

- Additional rope wraps on the cathead (1 ¾ wraps with counterclockwise rotation are standard)
- Improper drop height
- Rope condition
- Weather condition (e.g. wet rope vs. dry rope)
- Presence of rust, oil or grease on the cathead
- Friction between the hammer and hammer guide
- Insufficient slack in rope when releasing the hammer
- Hammer type (e.g. automatic, safety, donut, etc.)

The Dutch Cone (CPT) is the preferred method for obtaining in-place strength data in sands and silts. Standard Penetration Tests (SPT) will often underestimate the relative density of sands and silts below the water table due to heaving of soil into the auger stem or casing. Therefore, when drilling below the water table it is imperative that measures such as maintaining a positive head in the drill casing or hollow stem auger should be taken to prevent bottom heave.

The Vane Shear Test is recommended for organic silts and soft, plastic clays, that are free from rock particles. The equipment used is a shear device that measures the shear strength of soil in place. Use of the vane shear equipment is practical in soils that are so soft that adequate undisturbed samples cannot be obtained for laboratory tests or for supplementary shear test data to accompany laboratory testing. See AASHTO T 223 for instructions outlining procedures for performing in-place vane shear strength testing.

Full scale or modeled footing or pile load tests, or plate bearing tests can be used in special cases to estimate bearing capacity and deformation directly. However, on modeled footing or plate bearing tests, the zone of influence of the footing or plate may not extend into deeper and/or weaker (i.e. more compressible) materials if they exist.

Subsurface pre-determinations in the area being investigated could also be accomplished by using seismic refraction or reflection studies.

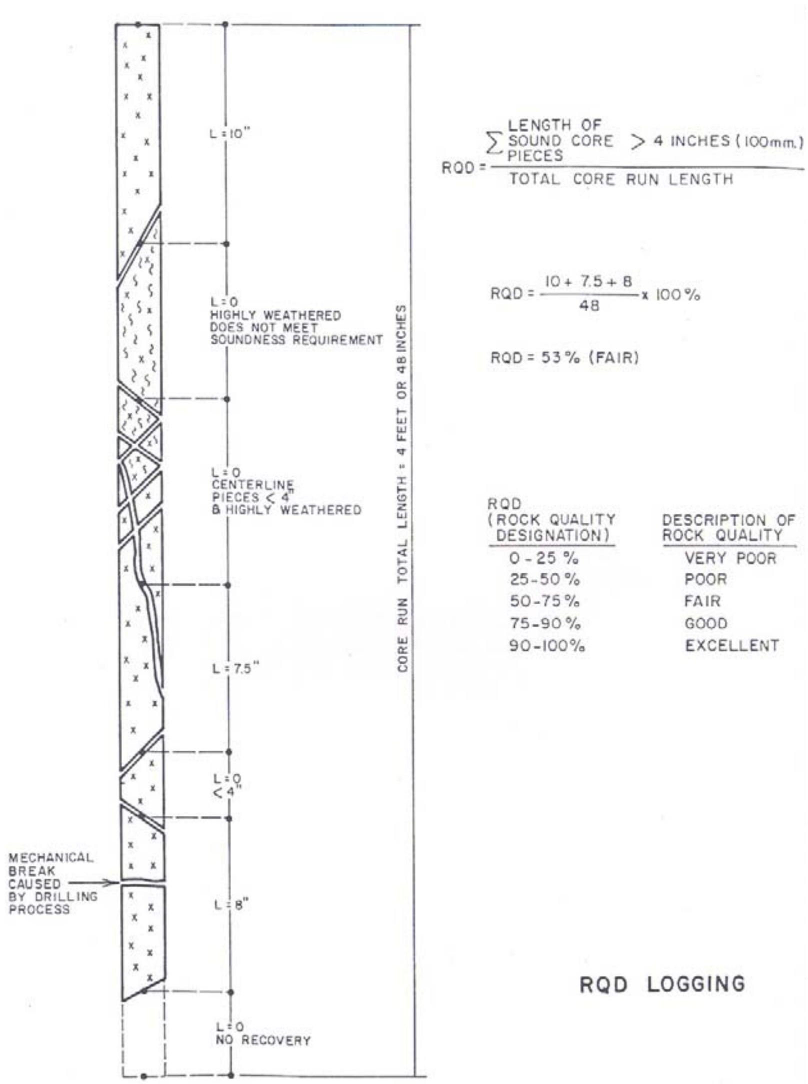
The following table indicates the recommended applications for available field testing methods. Test methods and references relating to exploration and field testing are listed in Section 455.00, References.

Test	Properties Measured	Appropriate Soil Type
Standard Penetration Test (SPT)- AASHTO T 206	Relative density in cohesionless soils, consistency in cohesive soils	All (may be unreliable in soft to firm clays, silts and in gravelly soils)
Solid Cone Penetrometer	Relative density (qualitative) approximate correlations with Standard Penetration in sands	All
Cone Penetration Test (CPT)- ASTM D3441	Continuous relative density, soil stratigraphy, in situ strength, undrained shear strength in clays	Sands, silts, clays (unreliable in gravels and cemented soils)
Field Vane Shear Test (FVT)- AASHTO T 223	Undrained shear strength, use with care, particularly in fissured, varved or highly plastic clays	Clays and clayey silts
Pressuremeter Test (PMT)- ASTM D4719	Compressibility	Soft rock and dense sand, gravel & till
Pumping Tests	Permeability	All (granular soils may require casing)
Dilatometer Test (DMT)	Empirical correlation for soil type, K_o, overconsolidation ratio, undrained shear strength, and modulus	Sand and clay
Seismic Refraction- ASTM D5777	Depth to rock, rock hardness/strength, rock quality, weathering, ripability	Soils underlying rock layers will not be detected. Correlate data with subsurface data from adjacent borings and/or test pits.
Plate Load Test- AASHTO T235	Bearing capacity, deformation modulus, modulus of subgrade reaction	All, may not measure deformation of deeper soils due to relatively shallow zone of influence

445.04.02 Field Testing for Rock.

Rock Quality Designation (RQD)

The Rock Quality Designation (RQD) is a modified core recovery percentage in which the lengths of all pieces of sound core over four (4) inches (100 mm) long (not including mechanical breaks that occurred during drilling) are summed and divided by the length of the core run. The correct procedure for measuring RQD is illustrated in the figure below.



The RQD is a rock quality index that indicates problematic rock (e.g. that is highly weathered, soft, fractured, sheared, and jointed) by lower RQD values. Thus, RQD is simply a measurement of the percentage of "good" rock recovered from an interval of a borehole. It should be noted that the original correlation for RQD reported by Deere (1963) was based on measurements made on NX-size core. Experience in recent years reported by Deere and Deere (1989) indicates that cores with diameters both slightly larger and smaller than NX may be used for computing RQD. Therefore, wire line cores using NQ, HQ, and PQ are considered acceptable. However, the smaller BQ and BX sizes shall not be used because of greater potential for core breakage and loss.

Core Piece Length Measurements

The core length should always be measured along the centerline.

Core breaks caused by the drilling process should be fitted together and counted as one (1) continuous piece. Drilling breaks are usually evidenced by rough fresh surfaces. For schistose and laminated rocks, it is often difficult to discern the difference between natural breaks and drilling breaks. When in doubt about a break, it should be considered as natural in order to be conservative in the RQD calculation for most uses. However, this practice would not be conservative when the RQD is used as part of a ripping or dredging estimate.

Soundness Assessment

Core pieces which are not "hard and sound" should not be included in the RQD calculation even though they possess the requisite 4-inch (100-mm) length. The purpose of the soundness requirement is to downgrade the rock quality where the rock has been altered and weakened either by surface weathering agents or by hydrothermal activity. Obviously, in many instances, experience and judgment must be used as to whether or not the degree of chemical alteration is sufficient to reject the core piece.

One commonly used procedure is to not include a piece of core if there is any doubt about its meeting the soundness requirement (e.g. because of discolored or bleached grains, heavy staining, pitting, or weak grain boundaries). This procedure may unduly penalize the rock quality, but it errs on the conservative side. Conversely, a second procedure which occasionally has been used is to include the altered rock in the RQD calculation, but to show it's inclusion by means of an asterisk (RQD*) which indicates that the soundness requirements have not been met. The advantage of this method is that the RQD* will provide some indication of the rock quality with respect to the degree of fracturing, while also noting its lack of soundness.

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Strength

The Point Load Test (ISRM) is recommended for the measurement of rock core strength. The Point Load Index, I_s, from the Point Load Test, should be converted to uniaxial compressive strength in the field. Various categories and terminology recommended for describing rock strength based on the point load test are presented in the following table:

Description	**Recognition**	**Approximate Uniaxial Compressive Strength, psi (kPa)**
Extremely Weak Rock	Can be indented by thumbnail.	36 to 145 (250 to 1000)
Very Weak Rock	Can be peeled by pocket knife.	145 to 725 (1000 to 5000)
Weak Rock	Can be peeled with difficulty by pocket knife.	725 to 3600 (5000 to 25000)
Medium Strong Rock	Can be indented 0.2 inches (5 mm) with sharp end of pick.	3600 to 7200 (25000 to 50000)
Strong Rock	Requires one (1) hammer blow to fracture.	7200 to 14500 (50000 to 100000)
Very Strong Rock	Requires many hammer blows to fracture.	14,500 to 36000 (100000 to 250000)
Extremely Strong Rock	Can only be chipped with hammer blows.	>36000 (>250000)

The above table also presents guidelines for common qualitative strength assessment while mapping or primary core logging at the investigated site by using a geological hammer and pocket knife. The field estimates should be confirmed where appropriate by comparison with selected laboratory tests.

Hardness

Rock hardness is commonly assessed by the scratch test. Descriptions and abbreviations used to describe rock hardness are presented in the following table.

TERMS TO DESCRIBE RELATIVE ROCK HARDNESS			
Description	**Hardness Designation**	**Field Test**	**Approx. Unconfined Compressive Strength, psi (MPa)**
Extremely Soft	R0	Can be indented with difficulty by a thumbnail. May be moldable or friable with finger pressure.	<100 (<0.7)
Very Soft	R1	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife or scratched with a finger nail.	100 to 1000 (0.7 to 7.0)
Soft	R2	Can be peeled with a pocket knife with difficulty. Cannot be scratched with a finger nail. Shallow indentation made by a firm blow of a geology pick.	1000 to 4000 (7.0 to 27.5)
Medium Hard	R3	Can be scratched by a knife or a geology pick. Specimen can be fractured with a single firm blow of a hammer/geology pick.	4000 to 8000 (27.5 to 55.0)
Hard	R4	Can be scratched with a knife or pick only with difficulty. Several hard hammer blows are required to fracture the specimen.	8000 to 16000 (55.0 to 110.0)
Very Hard	R5	Cannot be scratched with a knife or sharp pick. Specimen requires many hammer blows to fracture or chip. Hammer rebounds after impact.	>16000 (>110.0)

Other Hardness Scales such as the Mohs Scale can also be used to describe rock hardness.

445.05 Test Pits. Judgement and caution should always be used by field personnel when entering test pits. Test pits should not be entered by unqualified personnel. Test pits with vertical sides can be safely entered only when the total depth is less than five (5) feet and a qualified person has determined that no indication of a potential for cave-in exists per OSHA regulations. Field personnel should not enter test pits greater than five (5) feet deep with near vertical soil slopes. Test pits greater than five (5) feet deep should be excavated with a combination of vertical walls and horizontal benches that are proportioned so that the test pit walls are “sloped” (when averaging the change in test pit width over the depth) in accordance with OSHA guidelines.

445.06 Boring/Test Pit Closure. All borings shall be properly closed and sealed at the end of the subsurface investigation phase. Boring closure and sealing shall be accomplished in accordance with Idaho Department of Water Resources (IDWR) regulations and, as a minimum, all borings that encounter ground water shall be backfilled with bentonite hole plug to a depth of not less than 20 feet below the ground surface or to the bottom of the hole, whichever comes first. That portion of all borings extending through an existing road prism shall be backfilled with sand/cement grout or with aggregate and suitable pavement patching material, flush with existing finish grade.

All test pits shall be completely backfilled even with existing grade. That portion of the test pit that may remain in place after the proposed construction is completed shall be backfilled in maximum 2-foot-thick, loose lifts, and each lift be compacted with a large, vibratory compactor such as a hoepack.

SECTION 450.00 – GUIDELINES FOR SOIL AND ROCK CLASSIFICATION

450.01 Soil Classification. After performing a field description per ASTM D 2488 and performing appropriate soil index testing on the 3-inch-minus portion, all soils shall be classified in accordance with ASTM D 2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) as summarized in Figure 450.1. All persons classifying soils for ITD projects shall have read and be familiar with these ASTM methods. All final test pit or boring logs, including all soil and rock classification and description shall be prepared under the direct supervision and be checked by either a Professional Engineer or Geologist registered in the State of Idaho. The registered professional's full name shall appear on the final log. Field logs shall be modified to include final soil classifications, which should include as a minimum:

- Apparent consistency (for fine-grained soils) or density (for coarse-grained soils) adjective (Section 440.00)
- Water content condition adjective (e.g. moist) (Section 440.00)
- Color description (Section 440.00)
- Minor soil type
- Descriptive adjective for main soil type,
- Particle-size distribution adjective for gravel and sand,
- Plasticity adjective and soil texture (silty or clayey) for inorganic and organic silts or clays,
- Main soil type name (all capital letters),
- Descriptive term for minor soil type(s),
- Inclusions (e.g., concretions),
- The Unified Soil Classification System (USCS) group name and symbol in parenthesis appropriate for the soil type in accordance with AASHTO M145, ASTM D 3282, or ASTM D 2487.
- Geological or formation name (e.g., Pleistocene, Revett Formation), if known, (in parenthesis or in notes column).

The various elements of the soil description should generally be stated in the order given above. For example:

- Fine-grained soils: Soft, wet, gray, fat CLAY, trace fine sand, (CH), (Lacustrine, Clay of the Bonneville Flood Slack Water);
- Coarse-grained soils: Dense, moist, brown, silty, medium to fine, SAND, trace fine to coarse gravel (SM), (Alluvium of the Boise and Snake Rivers).

When changes occur within the same soil layer, such as change in apparent density, the log should indicate a description of the change, such as "same, except very dense".

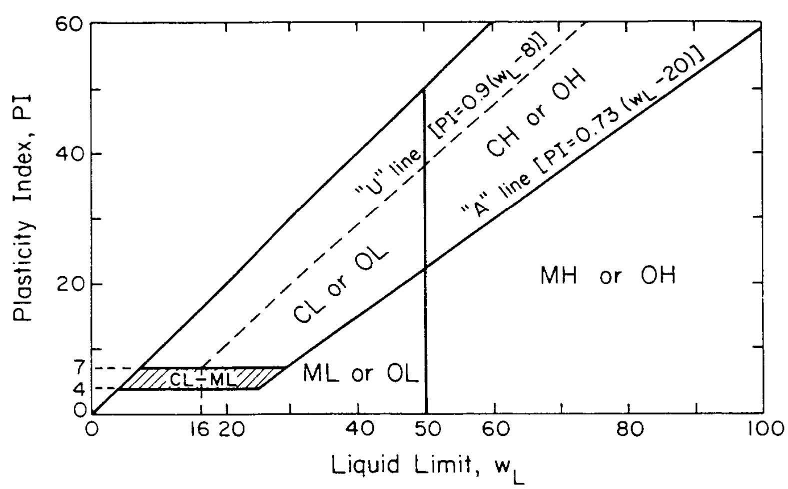
Figure 450.1

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse-Grained Soils More than 50 % retained on No. 200 sieve	Gravels More than 50 % of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5 % fines[C]	Cu ≥ 4 and 1 ≤ Cc ≤ 3[E]	GW	Well-graded gravel[F]
			Cu < 4 and/or 1 > Cc > 3[E]	GP	Poorly graded gravel[F]
		Gravels with Fines More than 12 % fines[C]	Fines classify as ML or MH	GM	Silty gravel[F,G,H]
			Fines classify as CL or CH	GC	Clayey gravel[F,G,H]
	Sands 50 % or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5 % fines[D]	Cu ≥ 6 and 1 ≤ Cc ≤ 3[E]	SW	Well-graded sand
			Cu < 6 and/or 1 > Cc > 3[E]	SP	Poorly graded sand[I]
		Sands with Fines More than 12 % fines[D]	Fines classify as ML or MH	SM	Silty sand[G,H,I]
			Fines classify as CL or CH	SC	Clayey sand[G,H,I]
Fine-Grained Soils 50 % or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K,L,M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K,L,M]
		organic	$\frac{\text{Liquid limit — oven dried}}{\text{Liquid limit — not dried}} < 0.75$	OL	Organic clay[K,L,M,N] / Organic silt[K,L,M,O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K,L,M]
			PI plots below "A" line	MH	Elastic silt[K,L,M]
		organic	$\frac{\text{Liquid limit — oven dried}}{\text{Liquid limit — not dried}} < 0.75$	OH	Organic clay[K,L,M,P] / Organic silt[K,L,M,Q]
Highly organic soils	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve.
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C] Gravels with 5 to 12 % fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay
[D] Sands with 5 to 12 % fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $\frac{(D_{30})^2}{D_{10} \times D_{60}} \approx C_c$
[F] If soil contains ≥ 15 % sand, add "with sand" to group name.
[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[H] If fines are organic, add "with organic fines" to group name.
[I] If soil contains ≥ 15 % gravel, add "with gravel" to group name.
[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.
[K] If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.
[L] If soil contains ≥ 30 % plus No. 200, predominantly sand, add "sandy" to group name.
[M] If soil contains ≥ 30 % plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 4 and plots on or above "A" line.
[O] PI < 4 or plots below "A" line.
[P] PI plots on or above "A" line.
[Q] PI plots below "A" line.



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The constituent parts of a given soil type are defined on the basis of texture in accordance with particle-size designators separating the soil into coarse-grained, fine-grained, and highly organic designations. Soil with more than 50 percent of the particles (by weight) larger than the (U.S. Standard) No. 200 sieve (0.074 mm) is designated coarse-grained. Soil (inorganic and organic) with 50 percent or more of the particles finer than the No. 200 (0.075 mm) sieve is designated fine-grained. Soil primarily consisting of less than 50 percent by volume of organic matter, dark in color, and with an organic odor is designated as organic soil. Soil with organic content more than 50 percent is designated as peat. The soil type designations follow ASTM D 2487; i.e., gravel, sand, silt, clay, organic silt, organic clay, and peat.

<u>Coarse-Grained Soils (Gravel and Sand)</u>

Coarse-grained soils consist of gravel, sand, and fine-grained soil, whether separately or in combination, and in which more than 50 percent of the soil (by weight) is retained on the No. 200 (0.075 mm) sieve. The gravel and sand components are defined on the basis of particle size as indicated in the following table:

Soil Component Description	**Grain Size**	**Determination**
Boulders*	>1 foot (>300 mm)	Measurable
Cobbles*	1 foot to 3 inches (300 to 75 mm)	Measurable
<u>Gravel:</u> Coarse Fine	 3 inches to ¾ inch (75 to 19 mm) ¾ inch to #4 sieve (19 to 4.75 mm)	 Measurable Measurable
<u>Sand:</u> Coarse Medium Fine	 #4 to #10 sieve #10 to #40 sieve #40 to #200 sieve	 Measurable and visible to the naked eye Measurable and visible to the naked eye Measurable and barely visible to the naked eye

*Boulders and cobbles are not considered soil or part of the soil's classification or description, except under miscellaneous description; e.g. with cobbles at about 5 percent (volume).

The particle-size distribution is identified as well graded or poorly graded. Well graded coarse-grained soil contains a good representation of all particle sizes from largest to smallest, with ≤ 12 percent fines. Poorly graded coarse-grained soil is uniformly graded with most particles about the same size or lacking one (1) or more intermediate sizes, with ≤ 12 percent fines.

Gravels and sands may be described by adding particle-size distribution adjectives in front of the soil type following the criteria given in Figure 450.1.

For sands and gravels containing more than 5 percent fines, the type of inorganic fines (silt or clay) can be identified by performing a shaking/dilatancy test. See fine-grained soils section.

Sand and gravel particles can be readily identified visually but silt particles are generally indistinguishable to the naked eye. With an increasing silt component, individual sand grains become obscured, and when silt exceeds about 12 percent, it masks almost entirely the sand component from visual separation. Note that gray, fine-grained sand visually appears siltier than the actual silt content.

Fine-Grained Soils

Fine-grained soils are those in which 50 percent or more (by weight) pass the No. 200 (0.075 mm) sieve, and the fines are inorganic or organic silts and clays as defined by the plasticity chart in Figure 450.1 and decrease in liquid limit (LL) upon oven drying. Inorganic silts and clays are those which do not meet the organic criteria as given in Figure 450.1. Dual symbols are used to indicate the organic silts and clays that are above the "A"-line. For example, CL/OL instead of OL and CH/OH instead of OH.

Highly Organic Soils

Colloidal and amorphous organic materials finer than the No. 200 (0.075 mm) sieve are identified and classified in accordance with their drop in plasticity upon oven drying (ASTM D 2487). Further identification markers are:

- Dark gray and black and sometimes dark brown colors, although not all dark colored soils are organic;
- Most organic soils will oxidize when exposed to air and change from a dark gray/black color to a lighter brown; i.e., the exposed surface is brownish, but when the sample is pulled apart the freshly exposed surface is dark gray/black;
- Fresh organic soils usually have a characteristic odor which can be recognized, particularly when the soil is heated;
- Compared to non-organic soils, less effort is typically required to pull the material apart and a friable break is usually formed with a fine granular or silty texture and appearance;
- Their workability at the plastic limit is weaker and spongier than an equivalent non-organic soil;
- The smear, although generally smooth, is usually duller and appears more silty;
- The organic content of these soils can also be determined by combustion test method (AASHTO T 267, ASTM D 2974).
- Unusually low in-situ dry unit weights and/or high moisture contents.

Fine-grained soils, where the organic content appears to be less than 50 percent of the volume (about 22 percent by weight) should be described as soils with organic material or as organic soils such as clay with organic material or organic clays etc. If the soil has an organic content higher than 50 percent by volume it should be described as peat. The engineering behavior of soils below and above the 50 percent dividing line presented here is entirely different. It is therefore critical that the organic content of soils be determined in the laboratory (AASHTO T 267, ASTM D 2974). Simple field or visual identification of soils as organic or peat is normally not advisable.

It is very important not to confuse topsoil with organic soils or peat. Topsoil is the thin layer of deposit found on the surface composed of partially decomposed organic materials, such as leaves, grass, small roots, etc. It contains many nutrients that sustain plant and insect life. These should not be classified as organic soils or peat, and should not be used in engineered structures.

Minor Soil Type(s)

In many soils two (2) or more soil types are present After completing the required laboratory index testing, minor soil types should be described and the overall soil description revised by following the procedures in ASTM D 2487 (Unified Soil Classification System).

Inclusions

Additional inclusions or characteristics of the sample can be described by using "with" and the descriptions described above. Examples are given below:

- With petroleum odor,
- With organic matter,
- With foreign matter (roots, brick, etc.),
- With shell fragments,
- With mica,
- With parting(s), seam(s), etc. of (give complete description of soils in partings, seams, etc.).

Geological Name

The soil description should include the origin of the soil unit and the geologic name, if known, placed in parentheses at the end of the soil description or in the remarks column of the boring or test pit log.

Laboratory Tests

The soil and/or rock samples obtained during the subsurface investigation should be submitted for laboratory tests. The test types will depend on the expected material use. For determination of the ballast requirement for a soil layer, the following tests, but not limited to, are generally required: Moisture And Density Relations of Soils, Gradation, Atterberg Limits, and R-Value. For cut slope or embankment stability analysis, tests that are generally required are: Unit Weight, Moisture Content, Atterberg Limits, Unconfined Compressive Strength, shear strength (Direct Shear or Triaxial), and Consolidation.

Soil Type Numbering

The first soil type encountered is to be designated as Soil No. 1. Any place this soil is subsequently found on the project, regardless of position, its designation will be the same. The second soil type encountered will be designated as Soil No. 2 and will be treated the same as Soil No. 1 described above, etc., until all of the different soils have been given a soil type designation. These soil type designations will be shown on the soil profile with appropriate symbols. The soil type designation and depth in the profile represented shall be shown on the ITD-1044 form submitted with the soil sample. Rock units are generally not given rock type designations on the subsurface profile.

450.02 Rock Classification. Rock classifications should use technically correct geological terms, although local terms in common use may be acceptable if they help describe distinctive characteristics. Rock cores should be logged when wet for color description consistency and greater visibility of rock features. The guidelines presented in the "International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests" (1978, 1981), should be reviewed for additional information regarding logging procedures for core drilling.

The rock's final lithologic description should include as a minimum the following items:

- Rock type,
- Color,
- Core recovery and RQD- see Section 445.00,
- Weathering and alteration- see Section 440.00,
- Strength and hardness- see Section 445.00,
- Rock discontinuity spacing, aperture size and infill- see also Sections 440.00 and 445.00.

Other relevant items such as grain size and shape, texture (stratification/foliation), mineral composition, and fracture description should also be evaluated and noted as appropriate for the project at hand.

The various elements of the rock's classification should be stated in the order listed above. For example:

> "Limestone, light gray, very fine-grained, un-weathered, strong, thin-bedded"

The rock description should also contain discontinuity and fracture identification, including a drawing of the naturally occurring fractures and mechanical breaks.

Rock Type

Rocks are classified according to origin into three (3) major divisions: igneous, sedimentary, and metamorphic. These three (3) groups are further subdivided into types according to mineral and chemical composition, texture, and internal structure. For some projects a library of hand samples and photographs representing examples of the lithologic rock types present in the project area should be maintained.

Color

Colors should be consistent with a Munsell Color Chart, and be recorded for the wet condition.

Grain Size and Shape

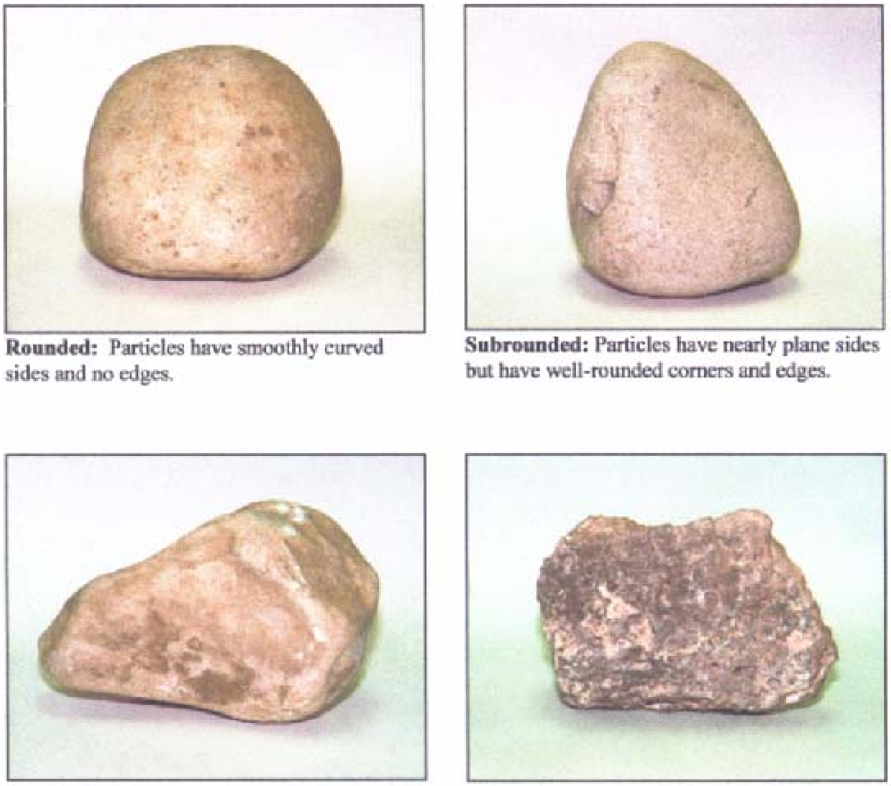
The grain size and shape descriptions, respectively, should be classified using the terms presented in the tables and Figure 450.2 below:

TERMS TO DESCRIBE GRAIN SIZE OF (TYPICALLY FOR) SEDIMENTARY ROCK		
Description	**Diameter, inches (mm)**	**Characteristic**
Very Coarse Grained	>0.20 (>4.76)	
Coarse Grained	0.08 to 0.20 (2.00 to 4.76)	Individual grains can be easily distinguished by the unaided eye.
Medium Grained	0.02 to 0.08 (0.42 to 2.00)	Individual grains can be distinguished by the unaided eye.
Fine Grained	0.003 to 0.02 (0.074 to 0.42)	Individual grains can be distinguished by the unaided eye with difficulty.
Very Fine Grained	<0.003 (<0.074)	Individual grains cannot be distinguished by the unaided eye.

TERMS TO DESCRIBE GRAIN SHAPE (FOR SEDIMENTARY ROCKS)	
Description	**Characteristic**
Angular	Showing very little evidence of wear. Grain edges and corners are sharp. Secondary corners are numerous and sharp.
Sub-angular	Showing Definite effects of wear. Grain edges and corners are slightly rounded off. Secondary corners are slightly less numerous and slightly less sharp than in angular grains.
Sub-rounded	Showing considerable wear. Grain edges and corners are rounded to smooth curves. Secondary corners are reduced greatly in number and highly rounded.
Rounded	Showing extreme wear. Grain edges and corners are smoothed off to broad curves. Secondary corners are few in number and rounded.
Well Rounded	Completely worn. Grain edges or corners are not present. No secondary edges or corners are present.

Figure 450.2

Criteria for describing angularity of coarse-grained particles - per ASTM D 2488-93 (see figures below)



Rounded: Particles have smoothly curved sides and no edges.

Subrounded: Particles have nearly plane sides but have well-rounded corners and edges.

Subangular: Particles are similar to angular description but have rounded edges.

Angular: Particles have sharp edges and relative plane sides with unpolished surfaces.

<u>Texture (Stratification/Foliation)</u>

Significant non-fracture structural features should be described. The thickness should be described using the terms in the table below. The bedding/foliation orientation should be measured from the horizontal with a protractor.

Descriptive Term	**Stratum Thickness, inches (mm)**
Very Thickly Bedded	>40 (>1000)
Thickly Bedded	20 to 40 (500 to 1000)
Thinly Bedded	2 to 20 (50 to 500)
Very Thinly Bedded	0.4 to 2 (10 to 50)
Laminated	0.1 to 0.4 (2.5 to 10)
Thinly Laminated	<0.1 (<2.5)

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Mineral Composition

If the mineral composition of the rock is identified, it shall be done by a geologist based on experience and the use of appropriate references. The most abundant mineral should be listed first, followed by minerals in decreasing order of abundance. For some common rock types, mineral composition need not be specified (e.g. dolomite, limestone).

Rock Discontinuities

Discontinuity is the general term for any naturally occurring, mechanical discontinuity in a rock mass having zero or low tensile strength. It is the collective term for most joint types, weak bedding planes, weak schistosity planes, foliation, weak zones, shear zones and faults. As a minimum, discontinuity descriptions should include discontinuity spacing, aperture size and infilling. Other discontinuity features should also be evaluated and described as presented below and as applicable to the project at hand. Discontinuity descriptive terms are presented in the table below.

The discontinuity spacing is the perpendicular distance between adjacent discontinuities. The spacing should be measured in inches (millimeters), perpendicular to the planes in the set.

The discontinuities should be described as closed, open, or filled. Aperture is used to describe the perpendicular distance separating the adjacent rock walls of an open discontinuity in which the intervening space is air or water filled. Width is used to describe the distance separating the adjacent rock walls of filled discontinuities. The terms presented in the following table should be used to describe apertures.

TERMS TO CLASSIFY DISCONTINUITIES BASED ON APERTURE SIZE

Aperture Size, inches (mm)	**Description**	
<0.004 (<0.1)	Very tight	"Closed Features"
0.004 to 0.01 (0.1 to 0.25)	Tight	
0.01 to 0.02 (0.25 to 0.5)	Partly open	
0.02 to 0.1 (0.5 to 2.5)	Open	"Gapped Features"
0.1 to 0.4 (2.5 to 10)	Moderately open	
>0.4 (>10)	Wide	
0.4 to 4 (10 to 100)	Very wide	"Open Features"
4 to 40 (100 to 1000)	Extremely wide	
>40 (>1000)	Cavernous	

Terms such as "wide", "narrow" and "tight" are also used to describe the width of discontinuities such as thickness of veins or fault gouge filling.

For the faults or shears that are not thick enough to be represented on the boring log, the measured thickness is recorded numerically in inches (millimeters).

In addition to the above characterization, discontinuities are further characterized by the surface shape of the joint and the roughness of its surface.

Filling is the term for material separating the adjacent rock walls of discontinuities. Filling is characterized by its type, amount, width (i.e., perpendicular distance between adjacent rock walls) and strength. The strength of any filling material along discontinuity surfaces can be assessed by the guidelines for fine grained soil consistency presented in Section 440.00. If non-cohesive fillings are identified, then identify the filling qualitatively, e.g., fine sand.

<u>Fracture Description</u>

The location of each naturally occurring fracture and mechanical break should be shown in the fracture column of the rock core log. The naturally occurring fractures are numbered and described using the terminology described above for discontinuities.

The naturally occurring fractures and mechanical breaks are sketched in the drawing column. Dip angles of fractures should be measured using a protractor and marked on the log. For non-vertical borings, the angle shall be measured and marked as if the boring was vertical, and the boring orientation shall be noted on the log. If the rock is broken into many pieces less than 1 inch (25 mm) long, the log may be crosshatched in that interval or the fracture may be shown schematically.

The number of naturally occurring fractures observed in each 20 inches (0.5 m) of core should be recorded. Mechanical breaks, thought to have occurred due to drilling, are not counted. The following criteria can be used to identify natural breaks:

1. A rough brittle surface with fresh cleavage planes in individual rock minerals indicates an artificial fracture.

2. A generally smooth or somewhat weathered surface with soft coating or infilling materials, such as talc, gypsum, chlorite, mica, or calcite obviously indicates a natural discontinuity.

3. In rocks showing foliation, cleavage or bedding it may be difficult to distinguish between natural discontinuities and artificial fractures when these are parallel with the incipient weakness planes. If drilling has been carried out carefully then the questionable breaks should be counted as natural features, to be on the conservative side (except for ripping and dredging studies).

4. Depending upon the drilling equipment, part of the length of core being drilled may occasionally rotate with the inner barrels in such a way that grinding of the surfaces of discontinuities and fractures occurs. In weak rock types it may be very difficult to decide if the resulting rounded surfaces represent natural or artificial features. When in doubt, the conservative assumption should be made; i.e., assume that they are natural (except for ripping and dredging studies).

The core logging results (frequency and RQD) can be strongly time dependent and moisture content dependent in the case of certain varieties of shales and mudstones having relatively weakly developed diagenetic bonds. A not infrequent problem is "discing", in which an initially intact core separates into discs on incipient planes, the process becoming noticeable perhaps within minutes of core recovery. The phenomena are experienced in several different forms:

1. Stress relief cracking (and swelling) by the initially rapid release of strain energy in cores recovered from areas of high stress, especially in the case of shaley rocks.

2. Dehydration cracking experienced in the weaker mudstones and shales which may reduce RQD from 100 percent to 0 percent in a matter of minutes, the initial integrity possibly being due to negative pore pressure.

3. Slaking cracking can be exhibited by some of the weaker mudstones and shales when subjected to wetting and drying.

All of these phenomena may make core logging of fracture frequency and RQD unreliable. Whenever such conditions are anticipated, core should be logged by an engineer or geologist as it is recovered and at subsequent intervals until the phenomenon is predictable. An added advantage is that the engineer or geologist can perform mechanical index tests, such as the Point Load Test (see Section 445.00), while the core is still in a saturated condition.

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SECTION 455.00 – REFERENCES

455.01 Idaho Standard Test Methods.

T62	Standard Method of Taking Undisturbed Soil Samples for Laboratory Consolidation, Shear and Permeability Tests
T142	Standard Method of Investigation of Aggregate and Borrow Deposits

455.02 AASHTO Test Methods.

M145	Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
T206	Penetration Test and Split-Barrel Sampling of Soils (see also ASTM D 1586)
T207	Thin-Walled Tube Sampling of Soils (see also ASTM D 1587)
T223	Field Vane Shear Test in Cohesive Soil (see also ASTM D 2573)
T225	Diamond Core Drilling for Site Investigation (see also ASTM D 2113)
T235	Bearing Capacity of Soil for Static Load on Spread Footings (see also ASTM D1194)
T254	Installing, Monitoring, and Processing Data of the Traveling Type Slope Inclinometer
T267	Determination of Organic Content in Soils by Loss on Ignition
T306	Progressing Auger Borings for Geotechnical Explorations

455.03 ASTM Test Methods.

D420	Standard Guide to Site Characterization for Engineering Design and Construction Purposes
D2487	Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2488	Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)
D2974	Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
D3282	Standard Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
D3441	Standard Test Method for Mechanical Cone Penetration Tests of Soil
D3550	Standard Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils for Geotechnical Purposes
D4220	Standard Practices for Preserving and Transporting Soil Samples

D4719	Standard Test Method for Prebored Pressuremeter Testing in Soils
D4750	Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
D5079	Standard Practices for Preserving and Transporting Rock Core Samples
D5092	Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers
D5777	Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation
D6032	Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core

455.04 Reports and Texts. The following typical references are available in the District or Headquarters Materials Section:

- “International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests” (1978, 1981).
- “Training Course in Geotechnical and Foundation Engineering, NHI Course No. 13231 – Module 1, Subsurface Investigations, Participant’s Manual”, Publication No. FHWA HI-97-021, November 1997.
- "Manual on Subsurface Investigations", NCHRP Final Report 24-1, July 1984, Haley and Aldrich, Inc.
- "Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications", FHWA, October 1985.
- "Proceedings of a Symposium on Site Exploration in Soft Ground Using In-Situ Techniques", FHWA Report TS-80-202, May 1978.
- "Guidelines for Cone Penetration Test, Performance, and Design", FHWA Report TS-78-209, July 1978.
- "Basic Procedures for Soil Sampling and Core Drilling", W. L. Acker III, Acker Drill Co., 1974.
- "Manual on Foundation Investigations", AASHTO, 1978.
- "In-Situ Measurement of Soil Properties", ASCE, Specialty Conference, Raleigh, North Carolina, June 1975.
- "Foundation Engineering Handbook", Fang, Kluwer Academic Publishers, July 1997, ISBN 0412988917.
- “Soils and Foundations Workshop Manual”, FHWA Publication No. FHWA HI-88-009, Second Edition, July 1993.
- “Soil And Rock Classification Manual”, Oregon DOT, Highway Division, 1987.
- “Guide For Utility Management”, ITD, September, 2003.